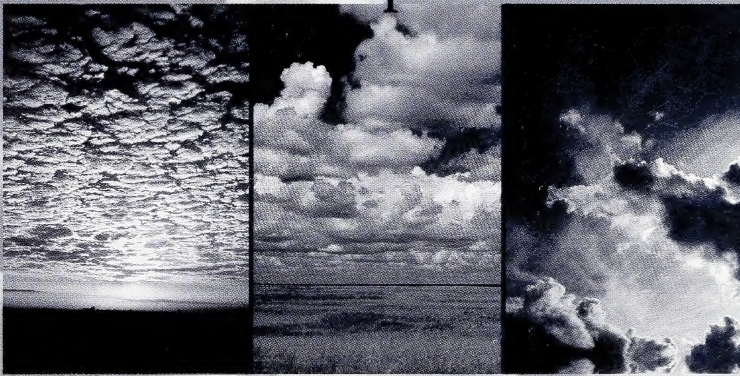
Alberta

SOE
State of the Environment Report



Air Quality

Alberta 1998

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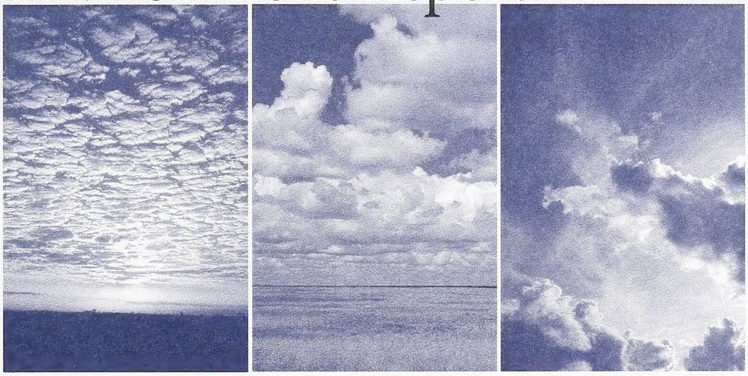

Air Quality

Alberta
ENVIRONMENT

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Alberta Air Quality at a Glance - 1998

Table 1.0

Summary of Alberta Air Quality 1998

Station	Air Quality Rating (number of hours*) Good	Fair	Poor	Very Poor
Edmonton Central	8638	101	1	0
Edmonton Northwest	8339	403	4	0
Edmonton East	8291	448	0	0
Calgary Central	8715	45	0	0
Calgary Northwest	8343	415	2	0
Calgary East	8584	175	0	0
Fort Saskatchewan	8352	404	4	0
Fort McMurray	7515	144	0	0

* The different totals reflect the number of hours each station was operational in 1998.

The above table is a snapshot of Alberta's air quality in 1998. The Index of the Quality of the Air (IQUA) is a system developed to provide the public with a meaningful measure of outdoor air quality. Using the IQUA, the air quality at each station is rated as Good, Fair, Poor or Very Poor every hour.

In 1998, the air quality in Alberta was rated as Good more than 95% of the time and either Good or Fair more than 99% of the year. There were only 11 hours when the air quality was reported as Poor and there were no incidents of Very Poor air quality.

What is the Index of the Quality of the Air (IQUA)?

The IQUA is a system developed to provide the public with a meaningful measure of outdoor air quality. From the IQUA, a description of Good, Fair, Poor or Very Poor is given to the current air quality.

The IQUA converts concentrations of five major air pollutants to a single number and a matching description. For example, a rating of 0-25 indicates Good air quality, 26-50 is Fair, 51-100 is Poor, and more than 100 is Very Poor air quality.

The IQUA is based on outdoor concentrations of carbon monoxide, the coefficient of haze (dust and smoke), nitrogen dioxide, ozone and sulphur dioxide. These pollutants are monitored continuously at three locations in Edmonton (central, northwest and east) and Calgary (central, northwest and southeast). An index value is calculated for air pollutants at each monitoring station. The concentration of each pollutant is converted to an IQUA number and the highest number becomes the IQUA for that station.

How was the IQUA Developed?

A federal-provincial committee originally developed the IQUA in 1978. Good, Fair, Poor and Very Poor air quality categories are related directly to guidelines under Alberta's *Environmental Protection and Enhancement Act*. These guidelines reflect the maximum desirable, acceptable and tolerable levels specified by the National Air Quality Objectives.

For each air pollutant, an IQUA rating of 25 corresponds to the federal maximum desirable level; a rating of 50 corresponds to the federal maximum acceptable level; and a rating of 100 corresponds to the federal maximum tolerable level.

How is the IQUA made available?

Alberta Environment provides this information through an automated air quality index reporting system. The monitoring stations are automatically polled every hour and the data are available by telephone.

The IQUA is calculated and issued hourly by Alberta Environment in Edmonton and Calgary. The current air quality index is available by phoning 780-427-7273 in Edmonton and 403-250-2099 in Calgary. (Or call 310-0000 toll-free from anywhere in the province.)

When is air quality a problem?

Fair or **Poor** air quality conditions usually occur when there is a strong temperature inversion and light winds. The combination of these weather conditions will often create a layer of cool, stagnant air near the ground. Air pollutants, emitted mostly by automobiles, are trapped in this layer of stagnant air. In Edmonton, these conditions usually occur with the approach of a warm front. In Calgary, strong temperature inversions are common before the arrival of a chinook.

Poor air quality can also occur in the heat of the summer. Under hot, calm weather conditions, photochemical smog can be formed through a complicated set of chemical reactions involving oxides of nitrogen and volatile hydrocarbons in the presence of sunlight. Photochemical smog has a noticeable light brown colour, and can reduce visibility and trigger respiratory response. In Alberta, photochemical smog is typically a concern only one or two days a year.

Very Poor air quality almost never occurs at Alberta monitoring stations.

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Preface

Alberta Environment is committed to informing Albertans about the state of the province's environment and produces many reports on the status of Alberta's environmental resources. This ensures accountability and gives Albertans important information for their own consideration and use. There is also a legislative basis for state of the environment reporting. Alberta's *Environmental Protection and Enhancement Act* requires the Minister of Environment to report annually on the state of the province's environment.

Nationally, the Canadian Council of Ministers of the Environment have promoted a common approach to State of the Environment reporting.

The purpose of State of the Environment (SOE) reporting is to provide timely, accurate and accessible information on ecosystem conditions and trends, their significance and societal responses, emphasizing the use of indicators.

SOE reports describe environmental conditions, pressures and responses to these conditions and pressures. They make extensive use of environmental indicators, key measurements that can be used to monitor, describe, and interpret change. Indicators can help us answer questions such as:

- What environmental trends are occurring?
- Why are they significant?
- What actions are being taken?

Education about the environment is an important goal of SOE reporting. In addition to facts and figures about the state of Alberta's environment, SOE reports feature background history and science to help the reader interpret the information presented.

The first Alberta State of the Environment Report was published in 1994. This was followed by SOE reports focussing on specific environmental topics:

- Waste management in 1995,
- Aquatic ecosystems in 1996, and
- Terrestrial ecosystems in 1997.

The theme of this SOE report is **air quality**.

Readers are invited to provide comments on this year's report or any aspect of SOE reporting to Alberta Environment at the address below. A reader survey form is enclosed at the end of this report. Your feedback is greatly appreciated.

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1.0 Introduction

1.1 The Atmosphere

The earth's atmosphere is the layer of gases that surrounds our planet. Our atmosphere is vital for life on earth. Our atmosphere provides oxygen to breathe, it insulates us and traps the heat from the sun, it protects us from harmful radiation from outer space, and it is the main mechanism by which water is distributed around the globe.

One of the by-products of the industrial age was the increased release of human-produced substances into the air. At the dawn of the Industrial Revolution, not much attention was paid to the emissions generated as a result of industrial production. Air quality began to be recognized as an issue in the late 1800s. As an example, the term "acid rain" was first used in the 1870s.

Over the last four decades, there have been many advances in our knowledge of air quality and pollution reduction strategies. As a result, many air pollutants have declined in concentration since the 1970s. As science improves, we are getting better at understanding the atmospheric processes that affect the quality of our air. However, despite the encouraging results, there is still concern about the quality of our air and the substances being released into our atmosphere.

There are many sides to the issue of clean air. Air quality is not only concerned with the physics and chemistry of the atmosphere. Economics, environment and even our lifestyle also enter into discussions on air quality.

Air quality is not an issue unique to Alberta. Throughout the world, the quality of the air is an important environmental concern.

Composition of the Atmosphere

The two major gases found in the atmosphere are nitrogen (78%) and oxygen (21%). Other gases found naturally in the air include argon (0.9%), water vapour, carbon dioxide and traces of various inert gases.

Water vapour in the atmosphere is essential to life on the planet. Without water vapour, there would be no clouds, no precipitation - essentially no weather.

Many substances in the atmosphere that we consider to be pollutants have natural sources as well as human ones. Volcanoes contribute sulphur dioxide (SO_2), hydrogen sulphide (H_2S) and particulates into the air. Forest fires add carbon monoxide (CO), while biological processes in the soil release nitrogen oxide (NO), nitrogen dioxide (NO_2) and nitrous oxide (N_2O).

Carbon dioxide (CO_2) is added to the air through biological decay. The oceans serve as both a source and **sink** for carbon dioxide.

Naturally occurring levels of ground-level ozone (O_3) in rural areas can exceed those levels found in urban areas. Many different types of organic chemicals, or hydrocarbons, are also emitted into the atmosphere by trees, vegetation, and the decay of plant and animal material.

While we have little control over natural emissions into the atmosphere, we do have control over the amounts of materials we release as a result of our activities.

It has been estimated that 90% of all sources of human-produced substances released into the atmosphere are the result of combustion of one kind or another (Henderson-Sellers 1984). We burn fossil fuels to heat our homes, power our vehicles and produce electricity. Most air emissions come from the incomplete combustion of these fuels. The materials released depend on the type of fuel burned and how efficiently the combustion takes place.

Most of the discussion about air quality is on the human-produced by-products of combustion, their effects and our efforts to reduce their impact.

Structure of the Atmosphere

The Earth's atmosphere can be divided into layers that are defined by height and temperature.

- **Exosphere** - 500 to 1,000 km above the Earth's surface
- **Thermosphere (also called Ionosphere)** - 85 to 500 km above the Earth's surface
- **Mesosphere** - 45 to 85 km above the Earth's surface
- **Stratosphere** - 15 to 45 km above the Earth's surface
- **Troposphere** - 0 to 15 km above the Earth's surface

We are concerned mainly with air quality in the troposphere - the layer of the atmosphere where we find our weather. An exception is the depletion of ozone occurring in the stratosphere.

Sink

A sink is "any process, activity or mechanism, which removes a greenhouse gas, an aerosol, or a precursor of a greenhouse gas from the atmosphere" (Melillo *et al.*, 1996).

1.2 Monitoring Air Quality

The first step to determine the quality of our air is to find out what is in the air. Monitoring programs help do that. There are two different types of air monitoring: **ambient air monitoring** and **emissions** or **source monitoring.**

The "Backbone" Provincial Air Quality Monitoring Network

Alberta has an innovative way of monitoring ambient air quality. The 'backbone' provincial monitoring network provides an integrated and focused network for monitoring air quality. The network helps relate ambient air quality data with human health and ecosystem data.

The primary focus of the program is to collect air quality data needed to address concerns regarding the potential impacts of air emissions on human health, livestock, crops, soil and water. Alberta Environment is responsible for managing the operations of the provincial monitoring network.

Figure 1

Alberta Environment Air Monitoring Station

In 1998, the provincial monitoring network consisted of 12 air quality stations and 10 precipitation quality stations. The provincial government, the federal government, airshed zones and industry operate these stations.

Ambient air monitoring

Ambient air monitoring evaluates an air sample from the general atmosphere. In Alberta, government agencies and private organizations conduct ambient monitoring

Emissions or Source Monitoring

Emissions or source monitoring measures the substances in emissions as they are released from their source. Many industries monitor their emissions to comply with government regulations.

The stations are located across the province (see Figure 2):

- Edmonton (3 sites operated by Alberta Environment),
- Calgary (3 sites operated by Alberta Environment),
- Fort Saskatchewan (operated by Alberta Environment),
- Sherwood Park (operated by the Strathcona Industrial Association),
- Fort McMurray (operated by the Wood Buffalo Environmental Association),
- Beaverlodge (35 km west of Grande Prairie - operated by Alberta Environment),
- Hightower Ridge (65 km northwest of Hinton - operated by the West Central Airshed Society), and
- Esther (40 km northeast of Oyen - operated by Environment Canada).

Table 2.0

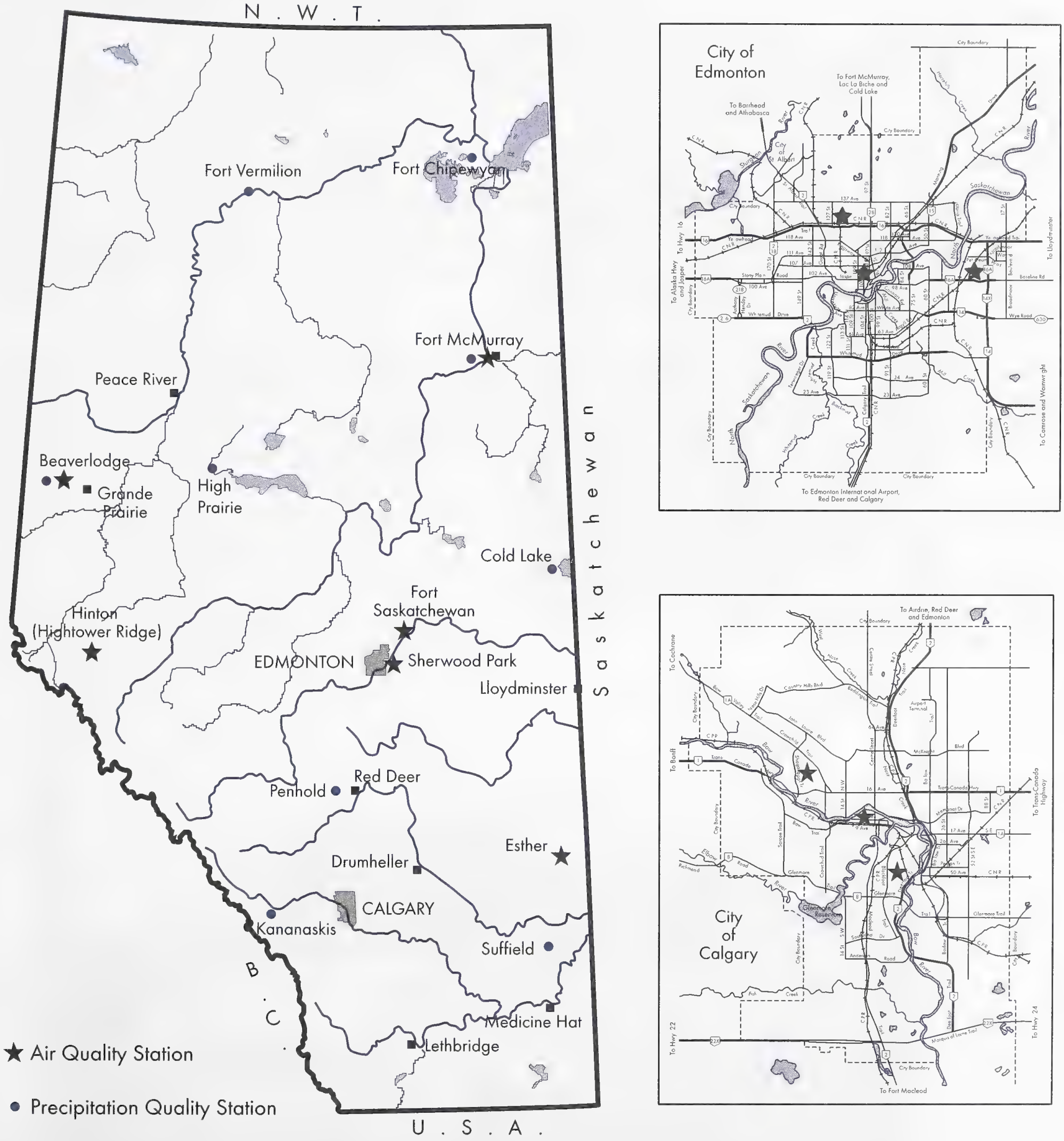
Air Parameters Measured by "Backbone" Monitoring Stations

Parameter	Edmonton Central	Edmonton Northwest	Edmonton East	Calgary Central	Calgary Northwest	Calgary East	Fort Sasktachewan	Sherwood Park	Fort McMurray	Beaverlodge	Hinton (Hightower Ridge)	Esther
Carbon Monoxide	X	X	X	X	X	X	X		X			
Dust and Smoke	X	X	X	X	X	X	X					
Inhalable Particulates	X	X		X					X	X		
Total Particulates	X	X	X	X	X	X	X					
Oxides of Nitrogen	X	X	X	X	X	X	X		X	X		
Ozone	X	X	X	X	X	X	X		X	X	X	X
Hydrogen Sulphide*			X			X	X	X	X			
Sulphur Dioxide			X			X	X	X	X			
Total Hydrocarbons	X	X	X	X	X	X	X	X	X			
Polycyclic Aromatic Hydrocarbons	X	X	X	X	X	X	X			X		
Volatile Organic Compounds	X		X	X								
Carbon Dioxide				X								
Ammonia							X					
Wind		X	X		X	X	X	X	X	X	X	X

* Measured as total reduced sulphur in Fort McMurray

Figure 2

Locations of Provincial Monitoring Stations (1998)



Other air quality values are monitored at some of the stations on an intermittent basis (every sixth day) as part of the National Air Pollution Surveillance (NAPS) system. Alberta Environment is also testing innovative methods to measure monthly concentrations for oxides of nitrogen, ground-level ozone, sulphur dioxide and volatile organic compounds.

Alberta Environment requires hundreds of industrial facilities across the province to monitor their emissions and local air quality. Special air quality monitoring surveys are also conducted by Alberta Environment. These surveys are conducted to:

- Obtain province-wide air quality data,
- Explore potential sites for Alberta's permanent monitoring network,
- Identify any potential problem areas, and
- Respond to specific air quality concerns from a community.

Many of these air quality surveys are conducted in response to public concerns or requests from municipal officials. Most special air quality surveys involve collecting air quality data using the Mobile Air Monitoring Laboratory (MAML).

Figure 3

Mobile Air Monitoring Laboratory (MAML)

The MAML is an 8.2-metre (27-foot) vehicle designed and equipped to measure air quality. It houses a variety of instruments that take air samples and analyze the samples on site. The MAML measures many different atmospheric substances (carbon monoxide, hydrogen sulphide, total reduced sulphur, sulphur dioxide, oxides of nitrogen, ozone, hydrocarbons and particulates) as well as weather conditions (wind speed, wind direction, temperature and relative humidity).

Some special air quality monitoring surveys may use other monitoring techniques to obtain measurements not provided by the MAML. For example, intermittent monitoring techniques may be required to measure volatile organic compounds, polycyclic aromatic hydrocarbons or sulphur compounds. In addition, passive techniques can be used to obtain longer-term concentrations of compounds such as sulphur dioxide, nitrogen dioxide, ozone, hydrogen sulphide or total sulphation.

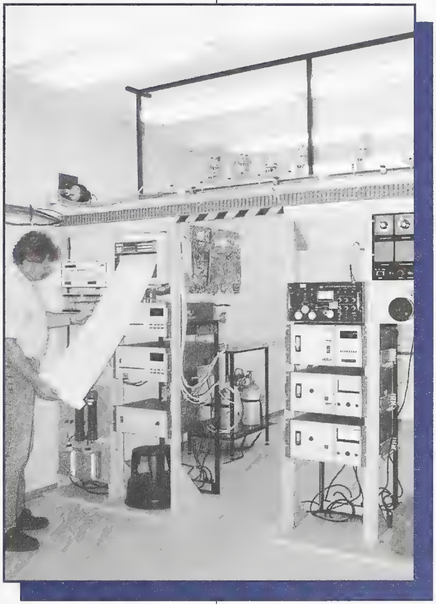


Figure 4

Air Monitoring Instruments

Data and information from Alberta Environment's air quality monitoring program are presented in monthly data reports, quarterly summary reports and annual interpretative reports. These reports are available through the Alberta Environment Information Centre at (780) 944-0313 (and toll-free by dialling 310-0000). Alberta Environment information on air quality is found at the department's web site at http://www3.gov.ab.ca/env/air.html. Air quality data collected by the backbone provincial monitoring network may be accessed directly at the CASA data warehouse, which is found on-line at http://www.casadata.org.

Regional Monitoring

In 1995, the Clean Air Strategic Alliance* (CASA) conducted a survey to determine current and future air quality monitoring needs for the province. The results indicated two main air quality concerns:

- The impact of air emissions on human health, and
- The effects of air quality on ecosystem health.

Recognizing these concerns, CASA proposed a new monitoring system for the province that would collect even better air quality data and allow Alberta to address air quality issues at local, regional and provincial levels.

* For more information about CASA, see section 3.1.

Some air quality issues in Alberta are local or regional, and are not easily addressed by a province-wide monitoring program. Therefore, CASA developed a program to measure air quality in specific zones right across the province.

The location and boundaries of an air quality zone depend on many factors. These factors include:

- Land use,
- Emission source types and volumes,
- Meteorological air pollution dispersion characteristics,
- Receptor types (human, vegetation, crops, land, water),
- Location of major population centres, and
- Unique management factors specific to each area.

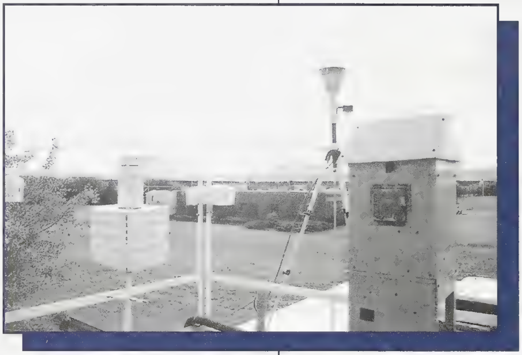


Figure 5

Air Monitoring Instruments

Ultimately, the success of a zone is largely dependent on the cooperation and dedication of local governments, industries and environmental organizations.

In October 1995, the West Central Airshed was the first air quality zone established in Alberta. The zone includes the communities of Drayton Valley, Edson, Hinton and Jasper. The key objective of the West Central Airshed program is to monitor the air and the effects that human-produced air emissions may have on vegetation in the zone. Sulphur dioxide, oxides of nitrogen, ozone, particulates, volatile organic compounds, wet and dry acid deposition are monitored in the airshed. The program is jointly funded by the industrial, agricultural, residential and transportation groups in the zone.

Figure 6

Airshed Zones

The West Central Airshed is recognized as an example for future zones proposed for the province. Recently, similar air quality zones have been established in the Rocky Mountain House/Sundre/Red Deer area (Parkland Airshed Management Zone) and Fort McMurray/Fort MacKay/Fort Chipewyan area (Wood Buffalo Zone).

Future Air Quality Monitoring Programs

The future "backbone" provincial monitoring network will be expanded to about 35 stations. A number of these sites are operating already and will only require upgrading to become part of the network. In addition, monitoring sites will be established to gather data on emissions that come from outside Alberta's borders, as well as data on flux and visibility. A second mobile monitoring unit may be added for use around the province. Ecological effects monitoring is proposed for each natural region of Alberta. This involves monitoring sensitive vegetation and soil characteristics, as well as air quality.

Figure 7

Air Monitoring Instruments

Province-wide monitoring provides information to evaluate relationships and detect longer-term trends. The data will be fed into an integrated data management system, making it available to those who need it. The system will be flexible and will be able to incorporate data gathered by other monitoring systems.

The provincial network is part of Alberta Environment's strategic plan to better address provincial and regional air quality concerns in Alberta. The plan represents a major step toward improving Alberta's present air quality monitoring system that was first established in the 1970s. The progress over the past several years is the direct result of cooperative efforts among representatives from industry, health and environmental groups, and the federal, provincial and municipal levels of government. Each of these groups shares a common goal: to develop a more efficient and effective air quality monitoring system in Alberta.

Further information on the provincial monitoring network is available on the CASA web site at http://www.casahome.org/.

2.0 Influences on Air Quality

2.1 Geography and Climate

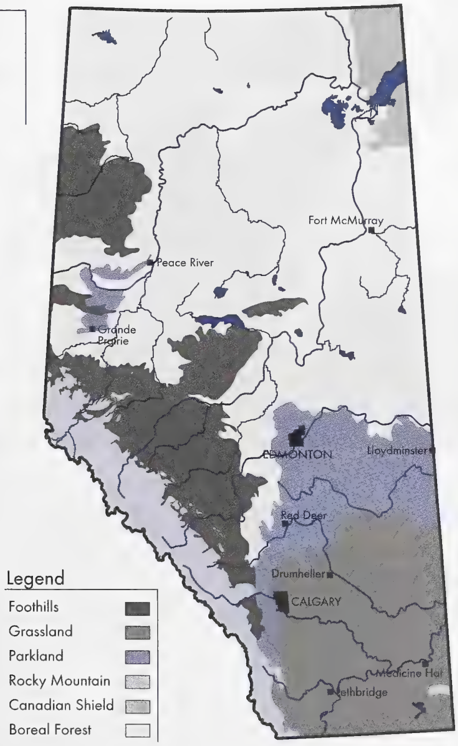
Alberta's Geography

While most of Alberta is relatively flat and rolling, there are also scattered uplands in the province, such as the Swan Hills, the Birch Mountains and the Cypress Hills. The major topographic features in Alberta are the foothills and Rocky Mountains on the province's western border. The Rocky Mountains play a significant role in defining Alberta's weather and climate, which, in turn, affects the air quality in the province.

The **natural regions** of Alberta reflect the varying soils, vegetation and climate of the province.

Figure 8

Alberta's Natural Regions



Grassland - The Grassland region, as its name suggests, is relatively flat terrain with few trees. Also known as Prairie, this region covers the southeastern portion of the province.

Parkland - The Parkland area is the transition zone between the Grassland and Boreal Forest and Foothill regions. It is characterized by rolling terrain mostly covered by aspen forest and small grassland clearings.

Boreal Forest - The Boreal Forest is the largest natural region in Alberta and is covered mainly by coniferous trees.

Foothills - The Foothills region is found as the elevation increases toward the mountains. This is a narrow band along the western edge of the province.

Rocky Mountains - Found along the western border of Alberta, the Rocky Mountains are characterized by high elevation vegetation and extreme climate.

Canadian Shield - The Canadian Shield covers the northeastern corner of Alberta. The Shield is an area of rock outcrops, lakes and relatively sparse vegetation.

Alberta's Climate

A "climatic normal" refers to the average weather values for a given location. In Canada, the minimum length of record required to establish a climatic normal is 30 years.

Alberta's climate is called "continental." Continental climates have no major water bodies close by to moderate weather patterns. As a result, extremes in temperature and precipitation are common. Alberta's climate has been described as "no two years are alike" (Phillips 1990).

Alberta has two major climate regions: the Prairie and Northwestern Forest Regions. (Environment Canada 1995) The Prairie climate region corresponds roughly with the Prairie and Parkland natural regions. The Northwestern Forest climate region covers most of the Boreal Forest, Foothills, Rocky Mountain and Canadian Shield natural regions.

Figure 9

Climate Regions of Canada

(adapted from Environment Canada 1995)

The Rocky Mountains influence both of Alberta's climate regions. The mountains block or modify the prevailing westerly winds before the winds reach Alberta. The mountains shield the province from the effects of the relatively warm waters of the Pacific Ocean, less than 500 km to the west. Without the moderating influence of the Pacific Ocean, temperatures in Alberta can range from +40°C to -40°C, a difference of 80°. In contrast, the temperatures found in a maritime climate, such as Vancouver, normally range from only from +28°C to -15°C - a difference of only 43° (Hare & Thomas 1974).

The Rocky Mountains also influence the amount of precipitation that falls in the province by creating a rain-shadow in the southeast corner of Alberta. As a result, this part of the province - in the Prairie climate region - features the driest conditions in Alberta. In fact, the Prairie region is one of the driest areas in Canada. Only the high Arctic receives less precipitation than the Prairie region. Precipitation in Alberta's two climate regions ranges from as little as 300 mm each year in the Prairie region to as much as 500 mm in the Northwestern Forest region yearly.

In winter, both climatic regions are subject to Arctic air producing episodes of very cold temperatures, light winds and clear skies. Summers tend to be relatively short and dry with long hours of sunshine and high temperatures (Phillips 1990).

Weather records in Alberta date back about 110 years in the major centres. Evidence of the climate that existed prior to these records is inferred from the analysis of lake sediments, tree rings and pollen studies (Environment Canada 1997b). Knowledge of past climates is helpful when discussing the issue of climate change.

2.2 Weather and its effect on Alberta's air Quality

Our weather plays a major role in determining the quality of our air. To better understand the role of weather and air quality, it helps to look at some basic meteorology. Meteorology is the science of weather - understanding how weather works and predicting weather patterns and events.

As mentioned earlier, the troposphere is the layer where weather occurs. Troposphere is taken from the Greek word "tropen" which means "to mix." The troposphere is characterized by significant amounts of water vapour and vertical mixing of the air. The mixing occurs because the sun heats the surface of the earth and the air at ground level, which rises because it is lighter than the cold air above it.

El Niño

El Nino has many impacts on weather worldwide. Every three to eight years, the easterly trade winds that usually blow west from South America to Australia subside. As a result, a large pool of abnormally warm water forms off the coasts of North and South America. This pool of warm water influences weather patterns over North America. This large scale warming in the equatorial Pacific off the coast of South America is called El Niño.

During a typical El Niño event, a high-pressure ridge forms over the southern United States. This allows warmer, drier air to flow into the southern Prairies. During El Niño winters in Alberta, temperatures are about 1° to 2°C above the long-term average and precipitation is about 10% below average for the December to February period. Natural runoff volumes are generally below average following El Niño winters.

La Niña

La Nina (the opposite of El Niño) is a large-scale cooling in the tropical Pacific waters off the coast of South America. La Niña is typically associated with an abnormally strong high-pressure system off the coast of South America. As a result, colder water exists in the eastern tropical Pacific. During a La Niña winter, colder than normal air presides over Alaska and western Canada with average temperatures 1 to 2 Celsius degrees below the long-term average. Precipitation is approximately 50% above average in December to February period and natural runoff volumes are above average following La Niña winters.

This mixing is responsible for the formation of clouds and precipitation. The mixing also helps to disperse substances in the troposphere.

In certain weather and topographical situations, a condition may arise where the air is stable and so tends not to mix vertically. This is usually caused by a **temperature inversion** and plays a major role in concentrating air pollutants in urban areas.

Much of our weather activity is defined by the **air masses** that move through our province. In Alberta, the main air masses that influence our weather are continental Arctic in the winter, and maritime Polar in the summer. As their names suggest, the maritime air masses are wetter than the continental air masses.

Continental Arctic air tends to produce cold, clear and dry weather conditions. Maritime air brings warmer temperatures, clouds and precipitation. The interaction of air masses creates much of our weather. For the most part, weather systems tend to move through the province very quickly.

This variability in our weather has an important effect on air quality in Alberta. While weather conditions can produce widespread temperature inversions and trap substances near the ground, such situations are uncommon in Alberta. There are local exceptions, but the quickly changing weather patterns help disperse air pollutants so concentrations tend not to build up.

Air Mass

An air mass is a region of air having uniform temperature and moisture characteristics. An air mass is named for the region of its origin. For example, continental Arctic air comes from the high Arctic away from any significant source of moisture and so the air is cold and dry.

What is a temperature inversion?

On a typical sunny day with relatively light winds, the air temperature is highest near the ground. This is because the ground has been heated by the sun, which in turn, heats the air closest to the ground. The air a few hundred metres above the ground is cooler than the air at the ground. As the evening approaches, the sun's energy decreases and the surface of the earth loses its heat to the atmosphere. As the ground cools, the lower levels of the atmosphere also cool. Eventually, the air close to the ground is cooler than the air a few hundred metres above the ground, creating a situation that is now the reverse of the daytime situation. This is referred to as a temperature inversion. The air is stable since there is cooler, heavier air below warmer, lighter air.

Temperature inversions will generally last longer during the winter and fall than in the spring and summer. In winter, temperature inversions can last all day. The combination of a strong temperature inversion and light winds may lead to a layer of cold, stagnant air near the ground. Substances emitted from low-level sources, such as vehicles, are trapped in this layer of air. A persistent temperature inversion may lead to increased concentrations of air pollutants in the lower atmosphere.

In Alberta, many incidences of fair or poor air quality are often related to temperature inversions. Warm air flowing across the mountains from the west can trap cooler air below. Any emissions released into the air may be trapped near the ground until the weather conditions change. Temperature inversions and still air conditions are very important when looking at air quality in Alberta.

2.3 The effect of Alberta's economy on air quality

The "emissions profile" of a region is a snapshot of the air quality in the area. Each region of Alberta has a unique emissions profile, because each region has different sources of emissions, topography and climate.

A region's air emissions are linked to its economy. As the economy grows, typically so do air emissions from human activity. As businesses and industries produce more goods and services for consumers, more people are employed, transportation needs increase, and demand for goods and services by individuals and organizations increase.

Alberta's economy and resulting air emissions depend a great deal on factors outside the province. Alberta has an open, trade-based economy that supplies goods and services to Canadian and international trading partners. In 1996, Alberta produced $20 billion worth of goods and services for the rest of Canada and $24 billion of goods and services for international export. Our gross domestic product that year was $74 billion. The largest single component, at over 40 % of exports, was oil and gas exports. A third of this amount went to the rest of Canada and the rest to the United States.

Producing and using fossil fuels create more air emissions in Alberta than any other activity. The production of synthetic crude oil from oil sands in northern

Alberta and the production of **upstream oil and gas** create significant air emissions. As well, significant air emissions are created by burning coal and natural gas to produce electricity and to transport goods throughout the province. All of these activities burn fossil fuels, which emit sulphur and nitrogen oxides, volatile organic compounds and greenhouse gases. While market demands outside Alberta drive oil and gas production activities, demand within the province determines the amount of fossil fuels used for transport and power generation.

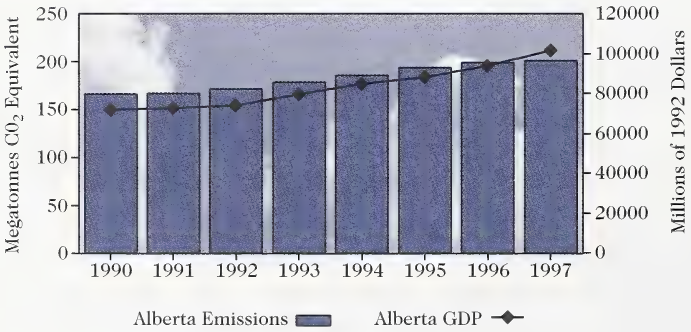
Figure 10 shows recent trends in greenhouse gas emissions and gross domestic product for Alberta. The two trends parallel one another in Alberta, as well as in the rest of Canada. However, the per capita level of emissions in Alberta is much higher than the rest of Canada since Alberta is a major fossil fuel producer for both Canada and the United States.

Upstream oil and gas

The portion of the oil and gas industry that explores for, acquires, develops, produces and markets crude oil and natural gas. Downstream oil and gas includes refineries and distribution to consumers.

Figure 10

Alberta Emissions vs. GDP



Economic activity is continuing to increase in Alberta. In fact, rising population and consumer demand in Alberta, Canada and the United States will create long-term energy demands. As a result, production of synthetic crude oil from the oil sands may double in the next 20 years.

Governments and industry have recognized that as populations and economic activity increase and emissions increase, air quality may deteriorate. As a result, technological solutions are being researched to avoid this outcome. For example, vehicle manufacturers have made impressive gains to the efficiency of modern cars and trucks. This will help stabilize and reduce emission levels despite increased transportation demands.

While reducing total emissions in Alberta is a significant challenge, progress is being made toward reducing emissions per unit of goods produced. Technology can help reduce emissions in cost-effective ways. In fact, technology created to reduce emissions will be marketable in its own right.

3.0
Air Quality Management in Alberta

In Canada, the federal and provincial governments have roles in managing the quality of our air. In Alberta, the *Environmental Protection and Enhancement Act* is the primary piece of legislation dealing with air quality.

3.1 CASA - The Clean Air Strategic Alliance

The Clean Air Strategic Alliance is a group that was formed by a process that began in March 1990 when the Alberta government announced the Clean Air Strategy for Alberta.

The Alberta Government developed the Clean Air Strategy in response to concerns, both in Alberta and around the world, about the environmental impacts of energy-related emissions from burning fossil fuels, such as oil, gas and coal. Given the energy industry's important role in the economies of Alberta and Canada, the strategy was a timely and necessary response.

The strategy was created using a broadly based, public consultation process. The consultations brought together people from various stakeholder groups in workshops throughout Alberta. One of the key recommendations from the process was to form the Clean Air Strategic Alliance (CASA).

CASA has identified a number of values important to its operation and to a vision for Alberta's air quality. These values include the following:

- Protecting human health and ecological integrity,
- Consensus decision-making,
- Sound scientific and economic knowledge,
- Open and transparent communications,
- Prudent action in areas of uncertainty and,
- Shared responsibility and accountability for decision-making.

The CASA Mandate

The Clean Air Strategic Alliance is a unique partnership of industry, government, environmental groups and other key stakeholder groups. Established in March 1994, CASA brings together a diverse range of interests to address air quality

CASA's vision for air quality in Alberta

The air will be odourless, tasteless, look clear and have no measurable short or long-term adverse effects on people, animals or the environment.

concerns through consensus. CASA's goal is to develop a new air quality management system for Alberta.

The following interests are represented on the CASA board of directors:

- Agriculture industry
- Federal government - Environment Canada
- Non-government organizations (NGOs)
  - Wilderness (Alberta Environmental Network (AEN) Wilderness caucus)
  - Pollution (AEN Energy caucus)
  - Pollution (AEN Air caucus)
  - Health
- Alternative energy Industry
- Forest industry
- Oil and gas industry
  - Canadian Petroleum Products Institute
  - Canadian Association of Petroleum Producers
  - Small Explorers and Producers Association of Canada
- Chemical manufacturers
- Local government
- Provincial government
  - Alberta Resource Development (more recently, Alberta Energy)
  - Alberta Health and Wellness
  - Alberta Environment
- Consumer/transportation representatives
- Mining industry
- Utilities

The Clean Air Strategic Alliance is accountable to its members and to the people of Alberta for its decisions. The Alberta government has agreed to approve and implement CASA decisions if they meet the following two criteria:

- Consensus must be reached among the stakeholders, and
- Decisions must be based on that consensus.

CASA carries out its mandate in the following ways:

- Clearly identifying the most important air quality issues,
- Prioritizing specific problems,
- Allocating and coordinating resources,

- Developing solution-oriented action plans, and
- Evaluating results.

The CASA mandate incorporates sustainability. CASA aims to pursue economic development in an environmentally responsible way and to improve the environment in an economically efficient way. CASA's commitment to consensus decision-making will give strength and direction to its many projects.

The Future

The Clean Air Strategic Alliance will continue to work on the following projects:

- ambient air quality monitoring,
- acidifying emissions management,
- zone coordination,
- human health and ecological effects monitoring, and
- air toxics and vehicle emissions management.

Every project maintains CASA's fundamental dedication to consensus decision making and accountability to the concerns and interests of citizens across the province. Future projects and studies may also come to CASA's attention as Alberta's population grows and industries expand. CASA's multi-stakeholder approach ensures these future concerns will be dealt with in a way that is open and transparent for all the parties involved.

3.2 Alberta's Air Quality Management System

Goals

Together, the members of CASA have developed the following goals to manage air quality in the province:

- to protect the environment,
- to optimize economic performance and efficiency, and
- to seek continuous improvement.

These goals are not separate elements. All three goals are taken into account when making decisions about air quality in Alberta.

Alberta Environment works toward these goals by using a regulatory management approach, which uses the following tools to apply the *Environmental Protection and Enhancement Act* and its regulations:

- policies,
- ambient air quality guidelines,
- facility approvals,
- source emission standards,
- plume dispersion modelling,
- ambient and source emissions monitoring
- reporting monitoring results and contaminant releases
- emissions inventories
- inspections and abatement strategies,
- enforcement, and
- research.

Policies

Alberta has a number of key policies to manage of industrial emissions to the atmosphere:

- Industrial facilities must be designed and operated in accordance with the pollution prevention principle. This means facilities must work to prevent pollution rather than having to deal with the emissions after they have occurred.
- Emissions from each industrial source must be controlled using
  - the best available control technology for carcinogens and
  - best available demonstrated technology that is economically achievable for other substances.
- Residual emissions must be dispersed through a stack designed to keep ambient concentrations below guidelines.
- Cumulative impacts from multiple sources must be considered.
- Industrial operators must monitor stack emissions and the resulting ambient concentration around their facilities to demonstrate compliance with emission limits and ambient guidelines or prescribed levels.
- Industrial operators must report the monitoring results to the government.

Pollution prevention

Pollution prevention strategies that avoid or minimize the creation of pollutants or wastes at the source.

Ambient Air Quality Guidelines

An ambient guideline is the maximum concentration of a substance that we would want to observe in the air around us. Sustained concentrations above the guideline could create adverse effects in humans and the rest of the environment.

Facility Approvals

Alberta Environment uses regulatory approvals issued under the *Environmental Protection and Enhancement Act* as the main tool for implementing the province's industrial air quality system. These approvals provide the following directions to industry:

- source emission limits,
- required pollution control equipment/technologies and allowable emission sources,
- operational procedures required to minimize emissions,
- stack design criteria based on plume dispersion modelling to ensure acceptable ambient levels are met, and
- environmental monitoring and reporting requirements, including emission inventory data.

Alberta Environment issues a single, integrated environmental approval to each industry or facility as required. Approvals cover all phases of industrial operations, including construction, operation, and reclamation. Approvals also address all environmental aspects including air, industrial wastewater, hazardous and solid wastes, groundwater, soils, sanitary sewage/waterworks, and reclamation and decommissioning aspects of facilities.

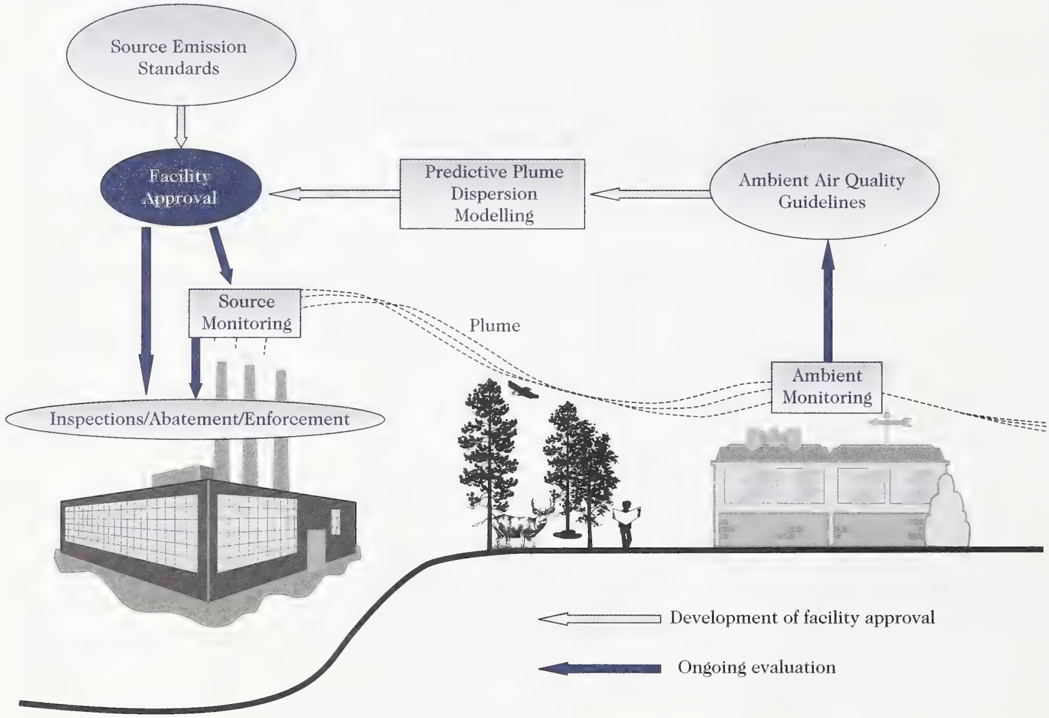
Approvals under the *Environmental Protection and Enhancement Act* can be issued for up to 10 years. The approval process also allows public input and has an appeal mechanism administered by the Environmental Appeal Board.

Source Emissions

To ensure that ambient air quality is maintained within guidelines, Alberta Environment restricts the emissions of various air contaminants that may be released by an industry or facility. Regulations and directives set the standards and Alberta Environment approvals manage the release of these source emissions. Under the approval system, regulated industries and facilities are allowed to emit limited amounts of these air contaminants. These emissions limits or source emission standards are specified in the approvals issued by Alberta Environment to each industry or facility.

Figure 11

Key elements of Alberta's Air Quality Management System



The source emission limits for any facility applying for an approval depend on the following:

- existing air quality,
- ambient air quality guidelines or prescribed ambient levels,
- source emission standards based on the
  - nature of the air contaminant, that is, carcinogenic or not
  - nature of the industry
  - air pollution control technology that is determined to be the best available demonstrated or best available
- results of plume dispersion modelling which takes into account the
  - local meteorology and terrain, and
  - surrounding emission sources.

Stack Monitoring

One way to monitor source emissions is to sample the quality of air right in the output stack of the industry or facility. There are two ways to take such a sample: manual stack surveys and continuous emission monitoring.

Manual stack surveys are short duration tests, usually consisting of three one-hour tests. These surveys are conducted by specially trained stack sampling personnel according to methods outlined in the *Alberta Stack Sampling Code*. The Code is updated periodically to reflect new methods and procedures.

In addition to conducting manual stack surveys, facilities that emit large quantities of substances must monitor emissions continuously. This is done with instruments permanently installed inside the stack. By measuring the concentration and flow rate, a facility or industry can determine its mass emission rate on an ongoing, year-round basis. Requirements are set out in the *Alberta Continuous Emission Monitoring Systems Code*.

Fugitive Emissions Monitoring

In some industries, mainly oil, gas and chemical plants, a significant amount of volatile organic compounds can escape from valves, flanges, sampling connections, pumps, pipe and compressors. Such emissions are commonly called **fugitive emissions**. Industries, especially organic chemical plants, are required to use monitoring programs to detect leaks, and to take corrective action, such as repairing or replacing equipment.

Fugitive emissions

Fugitive emissions are unintentional gas emissions from an installation, usually from improperly sealed joints in valves and piping.

Plume Dispersion Modelling.

Plume dispersion models are computer tools that link actual stack emissions to ambient concentrations. Once an emission limit for a particular source has been set, the models are used to determine the required stack height needed to properly disperse any residual air contaminants. Generally, the higher the stack, the lower the ground-level concentrations in the immediate area. The stack height must be high enough to ensure that the prescribed ambient levels are met. These models use information on emission characteristics - such as pollutant mass emission rate, gas temperature and flow rate - to predict the maximum ground level concentrations that may occur over a wide range of possible meteorological conditions, including the worst case atmospheric conditions. Modelling is also used to help determine the best position for air monitoring stations in the vicinity of industrial facilities.

Ambient Air Monitoring

Some industries are required to monitor ambient air quality for specific substances as part of the conditions in their approvals. The number of monitoring

stations, frequency and duration of monitoring or sampling, measuring or sampling techniques, and analytical methods, if necessary, depend on the substances to be monitored and their emission rates.

Ambient monitoring for air pollutants takes various forms. Perimeter monitoring consists of taking samples of chemical compounds at various locations along the property boundary of a plant for specified periods of time. The compounds are considered to be significant because of either the quantity involved or the potential health and environmental effects.

Ambient air quality can also be monitored by a permanent station located where the predicted maximum ground level concentration is expected to occur. Alberta Environment is researching other innovative ambient monitoring programs such as remote sensing.

Reporting Monitoring Results and Contaminant Releases

Industries are required to submit monitoring reports to Alberta Environment. Reporting requirements are specified in their approvals. The requirements vary depending on the chemicals, size and nature of the facility. The reports summarize ambient and source monitoring data. The reports also outline problems that may have arisen and corrective actions taken. The report formats are specified in Alberta Environment's *Air Monitoring Directive*.

Certain types of environmental incidents must be reported immediately. This requirement is outlined in the *Environmental Protection and Enhancement Act* and the associated *Release Reporting Regulation*. Alberta Environment's *Release Reporting Guideline* provides additional details on which situations must be reported immediately. The Release Reporting Guideline is available on the Alberta Environment web site under the Protection and Enforcement section at http://www3.gov.ab.ca/env/protenf/standards/index.html.

Emission Inventories

Emission inventories are used in many ways to manage air quality:

- To assess total emissions and emission trends,
- To perform sector-specific emission evaluations,
- To provide benchmarks for reference to national/international protocols and
- To plan zone/region airshed management and land use.

As a requirement of the *Canadian Environmental Protection Act*, Environment Canada compiles the National Pollutant Release Inventory (NPRI) each year. Anyone in Canada who owns or operates a facility that manufactures, processes or otherwise uses any of the NPRI-listed substances in sufficient quantities must file

a report with Environment Canada to identify any release or transfers of NPRI substances. There are currently 178 substances on the NPRI list. Information about air toxic emissions in Alberta is available in the NPRI database. More information on the inventory can be found on the NPRI Internet site at http://www.ec.gc.ca/pdb/npri/npri_home_e.cfm.

Every five years, Environment Canada and the provinces prepare a national inventory of sulphur dioxide, carbon monoxide, nitrogen oxides, hydrocarbons and particulate matter. Industries and facilities report their data on sulphur dioxide and nitrogen oxides to Alberta Environment through manual stack surveys, continuous emission monitors and estimates of flared emissions. They also report data to the Alberta Energy and Utilities Board on substances associated with well testing and **solution gas** conservation projects through flaring. Both Alberta agencies share this information to help Environment Canada complete their inventories.

Inspections and Abatement Strategies

The Compliance Inspection Program helps ensure that facilities meet the requirements of their approvals or registrations from Alberta Environment. Inspections are designed to identify and correct non-compliance. Significant non-compliance can be the subject of enforcement action. Whenever possible, inspectors emphasize prevention through education.

How frequently a facility is inspected depends on its priority. The department assigns all facilities a priority rating based on a number of factors. These factors can include the following:

· potential to cause an adverse effect,

· compliance history,

· environmental performance, and

· time elapsed since the last inspection.

Companies with greater potential to cause an adverse effect or with a history of non-compliance can expect to be inspected more frequently than others.

The majority of inspections are unannounced. Department inspectors can review and inspect all aspects of any facility's approval or registration. The review and inspection can include taking samples of soil, groundwater and effluent, and of air emissions at their source. If problems are identified, follow-up inspections ensure the appropriate actions have been taken. Failure to take the requested actions can result in enforcement action.

Enforcement

Alberta Environment's philosophy is to enforce regulations in a timely and consistent manner, and in a firm but fair fashion.

Infractions of environmental laws, such as legislation or approval conditions, are enforced with a wide range of tools, which are outlined in the *Environmental Protection and Enhancement Act*:

- warning letters,
- tickets,
- enforcement orders,
- administrative penalties,
- prosecutions,
- court orders, and
- cancellation of approvals.

The enforcement action taken depends on the circumstances surrounding the particular situation and the past history of the operation. Generally, companies experiencing difficulties in meeting Alberta Environment approval requirements will voluntarily take appropriate actions to meet the regulations.

Research

As an ongoing program to further learn about emissions and control mechanisms, Alberta Environment continues to fund the Alberta Research Council and other research institutions. Research topics include:

- ethylene effects on crop growth and yield under controlled environmental conditions,
- assessing natural terrestrial emissions of volatile organic compounds,
- characterizing airborne particulate matter from different sources,
- stack emissions of volatile organic compounds from sour gas plants,
- dioxins and furans in the ambient air,
- using lasers to measure ammonia emissions from treated hog manure, and
- best available technologies to remove liquid from solution gas directed to flare and the relationship between liquids in solution gas and flare combustion efficiency.

4.0 Alberta Air Quality Issues

A number of air quality issues affect Alberta and Albertans. These issues are not exclusive to Alberta, and examples can be found in other parts of Canada and rest of the world. This chapter examines a number of these issues from an Alberta viewpoint.

Statistics show our air quality is improving. Across Canada, concentrations of carbon monoxide, sulphur dioxide, oxides of nitrogen and suspended particles have all declined significantly since 1979 (Environment Canada 1996). Improvements in vehicle design and energy efficiency efforts have contributed to this decline. Personal awareness of air issues has also helped people take their own steps to reduce emissions.

4.1 Carbon Monoxide

Sources of Carbon Monoxide

Carbon monoxide (CO) is a colourless, odourless gas emitted primarily from the incomplete combustion of carbon-based fuels such as gasoline, natural gas and wood. The major source of CO in urban areas is motor vehicle exhaust. Vehicle emissions account for over two-thirds of the human-produced CO in the atmosphere (Environment Canada 1990). Minor human sources include fireplaces, industry, aircraft and natural gas combustion. CO is also found naturally in the atmosphere at very low levels (0.05 - 0.2 ppm*). Forest fires are a significant natural source of CO.

Carbon monoxide reduces the ability of blood to absorb and deliver oxygen to the organs of the body. In low concentrations, CO has been found to affect people with heart disease (Environment Canada 1990). At high concentrations, found above Alberta and Canadian standards, the symptoms include dizziness, headaches and fatigue. Exposure to high concentrations of the gas can be lethal. Every year, people die from CO exposure as a result of using inefficient heaters in poorly ventilated areas.

* parts per million

Carbon Monoxide in Alberta

The guidelines for the maximum permissible concentration of carbon monoxide are based on preventing adverse human health effects. Alberta has adopted the most rigorous of the national ambient air quality objectives for CO.

Alberta Guidelines Carbon Monoxide
One Hour - 13 ppm average concentration
Eight Hour - 5 ppm average concentration

In Alberta, the highest CO concentrations are detected at monitoring stations close to major roadways and tend to be short-lived. The high readings are a direct result of traffic during morning and evening rush hours. Concentrations also fluctuate seasonally. The highest concentrations occur during the late autumn, winter and early spring. High concentrations occur mainly because of meteorological conditions, such as temperature inversions and low wind speeds. Higher concentrations during the autumn and winter also occur because vehicles run less efficiently in cold weather and people tend to let their vehicles warm up and idle for longer periods.

1998 Levels of Carbon Monoxide

In 1998, there were only two occasions when the one-hour guideline for CO was exceeded in Alberta. The first was at the Calgary East station in January. The second occurred at the Edmonton Central station during October. In both cases, the high readings were associated with a stagnant weather pattern and high traffic volumes.

The eight-hour guideline was exceeded on four occasions during 1998. There were two days in January, one in Edmonton (Edmonton Central) and one in Calgary (Calgary Central and Calgary East), when the guideline was exceeded. In October, two days above the guideline were recorded in Edmonton (Edmonton Central). The high readings were caused by still weather conditions.

The majority of urban locations in Canada have shown a downward trend in carbon monoxide over the past 15 to 20 years. The average concentration of CO in Canadian cities has declined 70% between 1974 and 1992 (Environment Canada 1995). In Alberta, significant downward trends in CO levels are seen at the Edmonton Central, Edmonton Northwest, all Calgary stations and at the Fort Saskatchewan station based on data collected from 1980 to 1997. Decreases in annual average CO values of 77% and 60% are evident in downtown Edmonton and Calgary, respectively, based on data from 1980 to 1997.

How long should you let your car idle?

In most situations, you will use more fuel by letting your vehicle idle for longer than 20 seconds than if you turn it off and restart the engine.

ROVER

In October and November 1998, the CASA Vehicle Emissions Implementation Team welcomed the Roadside Optical Vehicle Emissions Reporter (ROVER) to Alberta. The ROVER van and equipment were on loan from the Ontario Ministry of the Environment. ROVER gathered data on Alberta vehicles, specifically the concentrations of carbon monoxide (CO) and carbon dioxide (CO_2) in the exhaust plumes of passing vehicles. Information on ROVER and its findings are posted on the CASA web site http://www.casahome.org.

Table 3.0

1998 Quarterly and Annual Averages (ppm) for Carbon Monoxide

Station	Jan - Mar 1998	Apr - Jun 1998	Jul - Sep 1998	Oct - Dec 1998	Annual Mean 1998
Edmonton Central	1.11 (1.47)	0.59 (0.86)	0.63 (0.84)	1.10 (1.38)	0.86 (1.14)
Edmonton Northwest	1.05 (1.28)	0.58 (0.68)	0.41 (0.77)	1.02 (1.28)	0.77 (1.00)
Edmonton East	0.54 (0.62)	0.37 (0.38)	0.31 (0.44)	0.53 (0.59)	0.44 (0.51)
Calgary Central	1.23 (1.54)	0.67 (0.88)	0.81 (0.94)	1.00 (1.47)	0.93 (1.21)
Calgary Northwest	0.76 (0.83)	0.51 (0.46)	0.56 (0.51)	0.69 (0.81)	0.63 (0.65)
Calgary East	1.14 (1.38)	0.50 (0.69)	0.70 (0.74)	0.97 (1.36)	0.83 (1.04)
Fort Saskatchewan	0.59 (0.65)	0.39 (0.34)	0.47 (0.39)	0.61 (0.62)	0.52 (0.50)

(Figures in brackets represent the average for 1981 to 1997)

The main reason for the decline in CO emissions is the continued improvement in vehicle emission control equipment over the past two decades. It is estimated that a car made in 1990 only produces 4% of the CO compared to a 1971 model (Environment Canada 1996). The overall reduction in CO concentrations is striking when you consider there are more vehicles on the road today than in 1971.

Figure 12

Long-Term Trend in Carbon Monoxide Concentrations

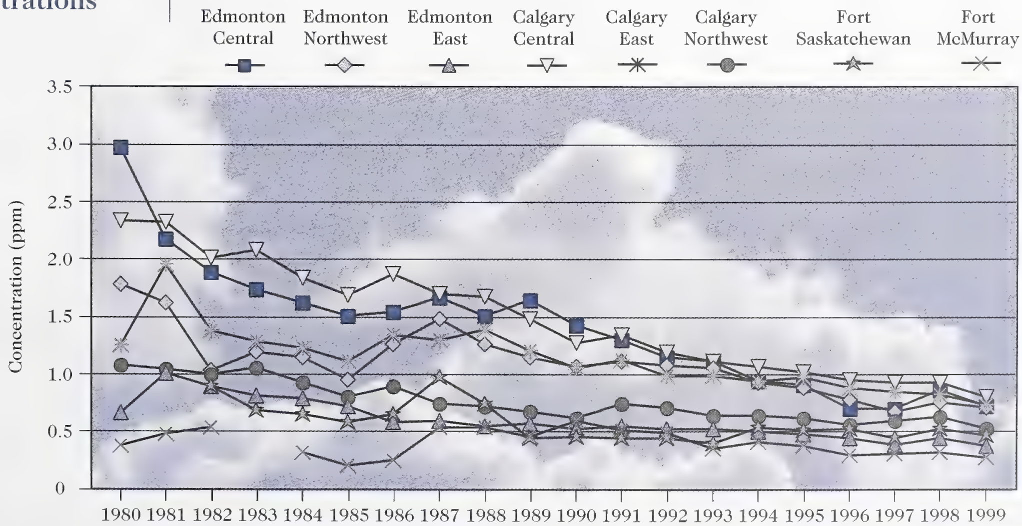


Table 4.0

Annual Average Carbon Monoxide Concentrations (ppm)

Year	Edmonton Central	Edmonton Northwest	Edmonton East	Calgary Central	Calgary Northwest	Calgary East	Fort Saskatchewan	Fort McMurray
1980	2.97	1.78	0.66	2.34	1.08	1.25	no data	0.37
1981	2.18	1.62	1.01	2.33	1.04	1.96	no data	0.48
1982	1.89	1.03	0.90	2.01	1.00	1.38	0.89	0.54
1983	1.74	1.20	0.82	2.08	1.06	1.29	0.69	no data
1984	1.62	1.15	0.79	1.84	0.93	1.23	0.65	0.32
1985	1.51	0.95	0.72	1.69	0.80	1.11	0.58	0.20
1986	1.54	1.27	0.58	1.88	0.89	1.34	0.65	0.25
1987	1.67	1.48	0.60	1.70	0.75	1.30	0.98	0.54
1988	1.51	1.27	0.55	1.68	0.72	1.39	0.74	0.54
1989	1.65	1.15	0.57	1.48	0.68	1.21	0.44	0.46
1990	1.43	1.07	0.53	1.28	0.62	1.06	0.46	0.59
1991	1.30	1.12	0.55	1.35	0.75	1.13	0.45	0.51
1992	1.15	1.08	0.53	1.20	0.71	0.99	0.45	0.49
1993	1.12	1.06	0.53	1.12	0.64	0.99	0.40	0.35
1994	0.94	0.93	0.50	1.07	0.64	0.94	0.54	0.41
1995	0.91	0.88	0.48	1.02	0.62	0.98	0.51	0.38
1996	0.70	0.78	0.45	0.95	0.56	0.88	0.52	0.30
1997	0.70	0.68	0.39	0.93	0.60	0.85	0.44	0.31
1998	0.86	0.76	0.44	0.93	0.63	0.83	0.52	0.32
1999	0.72	0.71	0.37	0.80	0.53	0.73	0.47	0.27

4.2 Oxides of Nitrogen

Sources of Oxides of Nitrogen

The terms "oxides of nitrogen (NO_x)" refers to the sum of nitric oxide (NO) and nitrogen dioxide (NO_2). During high temperature combustion - as in the burning of natural gas, coal, oil or gasoline - atmospheric nitrogen may combine with molecular oxygen to form nitric oxide. Nitric oxide is a colourless, odourless gas and has no known toxic effects. Most of the NO rapidly oxidizes to form nitrogen dioxide. NO_2 is a reddish-brown gas with a characteristicly pungent odour. NO_2 is partially responsible for the brown haze sometimes seen in urban areas. Oxides of nitrogen also contribute to acid deposition.

Oxides of Nitrogen in Alberta

In Alberta, about 34% of oxides of nitrogen emissions are produced by transportation (primarily vehicles), while 48% are due to industrial sources (mainly chemical, oil sands, upstream oil and gas) and 14% are due to coal-burning power plants (Environment Canada 1998). In Alberta cities, vehicles produce most of the oxides of nitrogen. Smaller sources of oxides of nitrogen include natural gas combustion and heating fuel combustion. Forest fires are a natural source of oxides of nitrogen.

The highest concentrations of oxides of nitrogen are generally recorded in the fall and winter at stations located downwind of major traffic arteries and areas of high traffic volume. Daily peaks are recorded during and after the morning and evening rush hours. As with other pollutants emitted by vehicles, higher levels of oxides of nitrogen are associated with vehicle emissions during stable weather conditions, such as strong temperature inversions and light winds.

The relevant ambient guidelines relate specifically to NO_2 concentrations. The maximum permissible concentrations are based on preventing human health effects.

Alberta Guidelines Nitrogen Dioxide (NO_2)
One Hour - 0.212 ppm average concentration
24 Hour - 0.106 ppm average concentration
Annual - 0.032 ppm arithmetic average

1998 Levels of Oxides of Nitrogen Dioxide

Air quality guidelines for NO_2 are rarely exceeded in Alberta cities. In 1998, all data collected in Edmonton, Calgary, Fort Saskatchewan, Fort McMurray and Beaverlodge were within the air quality guidelines. Although peak one-hour average concentrations do not exceed the air quality guidelines, overall average NO_2 concentrations are close to the annual guideline at the Calgary Central and Calgary East monitoring stations. The annual average NO_2 concentrations at these two stations in 1998 were 0.0308 and 0.0287 ppm, respectively, compared to an annual guideline of 0.032 ppm.

Annual average values in Calgary (0.026 ppm) were generally higher than those recorded in Edmonton (0.023 ppm).

Table 5.0

1998 Quarterly and Annual Averages for Nitrogen Dioxide (ppm)

Station	Jan - Mar 1998	Apr - Jun 1998	Jul - Sep 1998	Oct - Dec 1998	Annual Mean 1998
Edmonton Central	.033 (.035)	.021 (.023)	.024 (.020)	.030 (.029)	.027 (.027)
Edmonton Northwest	.030 (.029)	.020 (.018)	.018 (.016)	.028 (.027)	.024 (.023)
Edmonton East	.025 (.024)	.013 (.013)	.015 (.013)	.022 (.022)	.019 (.018)
Calgary Central	.040 (.040)	.027 (.028)	.026 (.025)	.031 (.035)	.031 (.032)
Calgary Northwest	.025 (.024)	.013 (.013)	.013 (.013)	.021 (.022)	.018 (.018)
Calgary East	.039 (.033)	.024 (.022)	.024 (.022)	.028 (.030)	.029 (.027)
Fort Saskatchewan	.019 (.019)	.009 (.009)	.009 (.008)	.017 (.017)	.014 (.013)
Beaverlodge	.007 (na)	.002 (na)	.002 (na)	.006 (na)	.004 (na)

Numbers in brackets represent the average for 1990-1998)

Higher NO_2 values in Calgary may be a result of stronger and more frequent temperature inversions due to the local topography and chinook winds. Higher levels in Calgary and Edmonton may also reflect higher numbers of vehicles than in other parts of the province. The NO_2 concentrations in Fort Saskatchewan (0.014 ppm) and Beaverlodge (0.004 ppm) were lower than values recorded in the larger Alberta cities.

Table 6.0

Annual Average Nitrogen Dioxide Concentration (ppm)

Year	Edmonton Central	Edmonton Northwest	Edmonton East	Calgary Central	Calgary Northwest	Calgary East	Fort Saskatchewan	Fort McMurray
1982	0.037	0.026	0.017	0.046	0.017	0.030	0.014	0.010
1983	0.027	0.025	0.018	0.036	0.018	0.027	0.018	0.012
1984	0.027	0.022	0.017	0.033	0.018	0.028	0.012	0.009
1985	0.029	0.019	0.018	0.036	0.017	0.026	0.013	0.009
1986	0.030	0.020	0.016	0.034	0.020	0.027	0.013	0.008
1987	0.031	0.020	0.016	0.034	0.020	0.025	0.014	0.010
1988	0.028	0.021	0.016	0.035	0.019	0.026	0.013	0.010
1989	0.026	0.022	0.016	0.035	0.020	0.029	0.009	0.010
1990	0.027	0.025	0.019	0.034	0.018	0.027	0.013	0.011
1991	0.029	0.026	0.021	0.037	0.018	0.026	0.013	0.010
1992	0.026	0.022	0.020	0.032	0.017	0.025	0.010	0.009
1993	0.027	0.021	0.016	0.031	0.017	0.026	0.013	0.005
1994	0.027	0.023	0.017	0.029	0.017	0.027	0.014	0.009
1995	0.026	0.019	0.017	0.028	0.018	0.027	0.014	0.009
1996	0.024	0.024	0.018	0.029	0.017	0.028	0.015	0.010
1997	0.025	0.026	0.018	0.030	0.018	0.029	0.014	0.010
1998	0.027	0.024	0.018	0.031	0.018	0.029	0.014	0.009
1999	0.024	0.022	0.017	0.028	0.016	0.025	0.013	0.009

In Canada over the past two decades, NO_2 concentrations have dropped at most urban locations. Based on annual average values, NO_2 levels decreased by 38% between 1974 and 1992 (Environment Canada 1995). However, this downward trend has levelled off over the last six years. Improvements in vehicle emission controls have been offset somewhat by the increasing number of vehicles on the road. It is anticipated these levels will begin to decline again as automobile technology continues to improve and alternate-fuel vehicles are introduced.

4.3 Ground-Level Ozone

Sources of Ozone

Ozone (O_3) is a colourless gas that is odourless at normal outdoor concentrations. At concentrations higher than 1 ppm, ozone has a characteristic sharp odour. Photocopiers, lightning and electrical discharges associated with arcing electric motors can sometimes produce ozone. Ozone is a component of **photochemical smog** sometimes generated near urban areas and industrial facilities in spring and summer.

Ozone is found near the ground and in the upper atmosphere. Stratospheric ozone depletion refers to the reduction of ozone in the upper atmosphere and is discussed in a later section of this report.

Unlike many other substances, ozone is not emitted directly from the exhaust pipe of a car or a factory stack. Ozone is considered a **secondary pollutant** since it is not directly released into the atmosphere. Ozone is created when an oxygen molecule (O_2) and an oxygen atom (O) combine. Natural processes produce most of the ozone found in the atmosphere.

One of the natural processes that produces ozone is the reaction of oxides of nitrogen and volatile organic compounds (primarily from vegetation) in the presence of sunlight. Ozone is also transported to ground level by mixing in the troposphere.

Most of the time, ozone concentrations are lower in the downtown cores of major cities than at rural locations. In urban areas, nitric oxide (NO) emitted from motor vehicles reacts with ozone to produce nitrogen dioxide (NO_2) and molecular oxygen (O_2). This reduces the amount of ground-level ozone in an urban area. In rural areas with less traffic, there is less nitric oxide to reduce the ground-level ozone.

In urban areas, ozone can be created on warm spring and summer days (above 20 to 25°C) when oxides of nitrogen and volatile organic compounds undergo a complicated set of chemical reactions in the presence of sunlight. This ozone, which is created from human-generated gases, adds to the natural ozone already in the atmosphere. This situation can cause elevated ozone levels downwind of large cities and industrial complexes.

Photochemical Smog

Photochemical smog is created by a combination of nitrogen oxides in the atmosphere and hydrocarbons released from vehicle exhaust, all in the presence of sunlight. The term "smog", combining the words smoke and fog, was first used in England in 1905 to describe air pollution.

Secondary Pollutant

A secondary pollutant is a pollutant that is not directly released into the atmosphere but is created when two or more substances combine in the atmosphere.

Ground-Level Ozone in Alberta

Alberta has high natural levels of O_3. The province's guidelines for ozone are based on preventing adverse effects to human health and vegetation. The air quality guidelines for ozone are currently under review by a federal-provincial committee.

Alberta Guidelines Ozone (ground level)
One Hour - 0.082 ppm average concentration

The one-hour guideline for ozone is occasionally exceeded at stations located near the edge of large cities or in communities located downwind of large urban or industrial areas during warm weather conditions. In 1998, the one-hour guideline was exceeded four times between July and September. The incidents occurred in Edmonton (2), Calgary (1) and Fort Saskatchewan (1). All of these episodes occurred during hot weather conditions. These situations were likely caused by a high concentration of natural ozone along with an increased level of ozone generated as a result of human-generated precursor gases. In 1997, the one-hour guideline for ozone was not exceeded in Alberta.

In Alberta cities, elevated ozone levels and associated photochemical smog are typically a concern only one or two days a year. Photochemical smog is considered a serious air pollution problem in other parts of Canada, specifically the Lower Fraser Valley of British Columbia, the Windsor-Quebec corridor, Nova Scotia, and New Brunswick.

Based on data from 1990 to 1997, the one-hour guideline for ozone in Edmonton and Calgary was exceeded an average of 0.6 and 0.3 hours per year per station, respectively. This is much lower than large cities in Ontario and Quebec where the one-hour guideline for ozone is exceeded up to 14 hours per year per station based on 1990 to 1994 data.

Table 7.0

Annual Average Ozone Concentration (ppm)

Year	Edmonton			Calgary			Fort	Fort
	Central	Northwest	East	Central	Northwest	East	Saskatchewan	McMurray
1982	0.014	0.021	0.024	0.012	0.022	0.016	0.027	0.021
1983	0.013	0.019	0.023	0.012	0.022	0.015	0.022	0.019
1984	0.015	0.017	0.020	0.013	0.023	0.015	0.026	0.021
1985	0.015	0.016	0.025	0.013	0.024	0.016	0.024	0.020
1986	0.016	0.017	0.022	0.012	0.022	0.017	0.021	0.020
1987	0.021	0.019	0.022	0.014	0.023	0.017	0.024	0.022
1988	0.016	0.018	0.022	0.016	0.023	0.017	0.025	0.022
1989	0.015	0.017	0.020	0.015	0.024	0.016	0.021	0.023
1990	0.014	0.018	0.021	0.014	0.023	0.018	0.025	0.025
1991	0.017	0.020	0.020	0.015	0.025	0.018	0.027	0.022
1992	0.016	0.017	0.021	0.013	0.021	0.015	0.020	0.021
1993	0.017	0.017	0.021	0.013	0.021	0.014	0.022	0.022
1994	0.020	0.020	0.023	0.015	0.024	0.017	0.027	0.024
1995	0.014	0.016	0.022	0.012	0.021	0.015	0.025	0.019
1996	0.016	0.015	0.022	0.014	0.023	0.017	0.025	0.018
1997	0.016	0.018	0.020	0.014	0.022	0.015	0.021	0.017
1998	0.016	0.020	0.023	0.014	0.023	0.015	0.022	0.021
1999	0.017	0.018	0.024	0.015	0.022	0.017	0.024	0.021

1998 Levels of Ground-Level Ozone

Ozone levels in Fort Saskatchewan exceed the one-hour guideline more frequently than in Edmonton and Calgary. Higher ozone levels in the Fort Saskatchewan area are likely due to the combination of natural ozone and ozone resulting from vehicles and industry emissions in the Edmonton area that are transported to the Fort Saskatchewan area by the prevailing winds. This situation usually occurs in the afternoon on warm spring and summer days. The figures for monitoring stations in the mountain foothills show high levels for naturally occurring ground-level ozone.

Small upward trends in long-term ozone concentrations are seen in data collected at the Edmonton Central and Calgary Central monitoring stations. This trend in downtown Edmonton and Calgary seems to be related to lower concentrations of nitric oxide in the downtown cores.

Table 8.0

1998 Quarterly and Annual Averages for Ozone (ppm)

Station	Jan - Mar 1998	Apr - Jun 1998	Jul - Sep 1998	Oct - Dec 1998	Annual Mean 1998
Edmonton Central	.012 (.013)	.025 (.024)	.019 (.017)	.009 (.010)	.016 (.016)
Edmonton Northwest	.013 (.015)	.031 (.027)	.025 (.018)	.010 (.010)	.020 (.018)
Edmonton East	.018 (.020)	.034 (.030)	.024 (.021)	.015 (.014)	.023 (.021)
Calgary Central	.009 (.011)	.021 (.021)	.017 (.016)	.009 (.008)	.014 (.014)
Calgary Northwest	.017 (.020)	.031 (.031)	.027 (.024)	.015 (.016)	.023 (.023)
Calgary East	.010 (.013)	.023 (.024)	.018 (.018)	.009 (.010)	.015 (.016)
Fort Saskatchewan	.017 (.024)	.032 (.033)	.024 (.023)	.014 (.015)	.022 (.024)
Beaverlodge	.028 (na)	.035 (na)	.028 (na)	.024 (na)	.029 (na)

(Numbers in brackets represent the average for 1988-1998)

4.4 Volatile Organic Compounds

Sources of Volatile Organic Compounds

Volatile organic compounds (VOCs) include a large number of substances that contain hydrogen (H), carbon (C) and possibly other elements. VOCs evaporate easily. Some react with oxides of nitrogen in the presence of sunlight to form ozone and photochemical smog. Other VOCs are toxic to humans, animals or vegetation. Methane (CH_4) is not a VOC.

Volatile organic compounds are produced by both natural and human sources. Total VOC emissions from natural sources - mainly forests - are estimated to be six times greater than from human sources in Canada. Other natural sources of VOCs include grasslands, wetlands and water bodies.

Human-generated sources of VOCs include vehicle emissions, gasoline marketing and storage tanks, petroleum and chemical industries, dry cleaning, fireplaces, natural gas combustion and aircraft. The major human-generated sources of volatile organic compounds are motor vehicles and industrial plants. VOCs, such as ethylene, propylene, toluene, m-xylene and p-xylene are major components of

vehicle exhaust. Butane and isopentane are major components of gasoline vapour. Propane is emitted by propane-fuelled vehicles and from propane storage and distribution. VOCs are also produced by various industrial processes and when solvents and organic chemicals evaporate. A notable amount of VOC emissions result from small leaks in valves, flanges, sampling connections, pumps, pipes and compressors at industrial facilities.

Volatile Organic Compounds in Alberta

In 1994, total emissions of VOCs from human sources in Alberta were 745,000 tonnes, almost 30% of the national total (Environment Canada 1995). In the industrial process category, almost 94% of emissions came from upstream oil and gas operations. Automobiles make up almost 50% of the transportation sector emissions and general solvent use accounted for 85% of the miscellaneous category.

Over 150 VOCs are monitored in the downtown cores of Edmonton and Calgary, as well as in the industrial area of east Edmonton. Monitoring for VOCs at the Edmonton Central, Edmonton East and Calgary Central stations began in 1991 with the co-operation with Environment Canada.

Some individual VOCs are believed to be a threat to human health. For example, benzene is classified as carcinogenic (cancer causing) to humans and hexane as a cause of nervous system disorders.

In the presence of sunlight, many VOCs can react to form secondary pollutants, which can produce smog or ground-level ozone downwind of urban centres and industrial complexes. As a result, public concern has increased regarding potential health risks posed by VOCs in the urban environment.

Not all VOCs are equally effective at producing ozone. For this reason, VOCs often are classified in terms of their reactivity, or their tendency to contribute to the build up of photochemical smog (Carter 1991). The top 10 VOCs measured in Alberta that contribute to the potential formation of smog are:

- ethylene
- m-xylene and p-xylene
- propylene
- toluene
- 1,2,4-trimethylbenzene
- isobutene
- butane
- isopentane
- pentane
- propane

These volatile organic compounds account for over 60% of the potential ozone and smog formation from VOCs at the Edmonton and Calgary monitoring stations (Bates and Aklilu 1998).

Concentrations of ethylene, m-xylene and p-xylene, propylene, toluene, 1,2,4-trimethylbenzene and isobutene were substantially higher at the Edmonton Central and Calgary Central stations than the Edmonton East station. The major source of these VOCs in downtown Edmonton and Calgary is vehicle exhaust emissions. At the Edmonton East station, which is considered an industrial location, alkanes such as butane, isopentane, pentane and propane play a more important role in potential smog formation. In 1997, concentrations of these VOCs were at least twice as high in east Edmonton as in downtown Edmonton and Calgary. In addition, a downward trend based on annual medians from 1991 to 1997 is evident for butane, isopentane and pentane at the Edmonton East monitoring station. A statistically significant downward trend in toluene is also evident based on annual median values from 1991 to 1997.

The issues surrounding VOCs are quite complex. Alberta is working with other provinces and the federal government to address VOCs in the environment. To deal with both nitrogen oxides and volatile organic compounds, Alberta has implemented relevant parts of the Management Plan for Nitrogen Oxides (NO_X) and Volatile Organic Compounds (VOCs) developed by the Canadian Council of Ministers of Environment (CCME).

Regarding ground-level ozone, the CCME has developed a federal-provincial plan to manage emissions of NO_X and VOCs. The plan has two main objectives:

- To resolve existing NO_X and VOC-related environmental problems in Canada, and
- To meet Canadian international obligations relating to NO_X and VOCs.

The CCME is also studying the direct effects of VOCs on the environment in order to develop standards for these compounds. For some VOCs, the standards from other jurisdictions, such as the United States, are being considered for use in Canada. For other compounds, studies are looking at creating new standards that will be acceptable across the country.

4.5 Acid Deposition

Sources of Acid Deposition

Acid deposition or "acid rain" is a well known air quality issue. While Canadians have become aware of "acid rain" over the past 30 years, the term dates back even further. Robert Angus Smith first used the term in his 1872 publication, *Air and Rain: The Beginnings of Chemical Climatology*, to describe the sooty skies over Manchester, England.

Acid deposition can occur through two separate processes - **wet deposition** or **dry deposition**. Wet deposition, or acidic precipitation, occurs when acidic substances, such as sulphur dioxide (SO_2) or oxides of nitrogen (NO_x), combine with water in the atmosphere. The resulting mixture is more acidic than normal precipitation. When the precipitation falls to earth, it affects vegetation, soils and water bodies.

"Wet deposition" is precipitation (rain, hail, sleet, snow or fog) that has a pH of less than 5.6. Although neutral substances have a **pH** of 7, "pure" precipitation has a pH of approximately 5.6. This is because unpolluted precipitation is normally a dilute solution of carbonic acid, which is formed when atmospheric carbon dioxide (CO_2) dissolves with atmospheric water and creates slightly acidic precipitation.

With "dry deposition," gaseous or aerosol compounds interact directly with surface water, vegetation and soils in a variety of ways to create acidic compounds. In certain regions of the world, dry deposition can have more of an environmental effect than wet deposition. In fact, dry deposition can be the major cause of total acidic deposition in such areas.

Sulphur dioxide (SO_2) is one of the main compounds that contributes to acid deposition. SO_2 is formed when fossil fuels, such as coal and natural gas, are burned to generate electricity, to heat homes, and to power vehicles. During combustion, sulphur (S) is released from the fossil fuel and combines with oxygen (O_2) to form SO_2. Coal-burning plants are significant sources of SO_2 emissions, which explains the high value placed on low-sulphur coal for power generation. Sulphur dioxide can also combine with moisture in the atmosphere to form a weak form of sulphuric acid (H_2SO_4).

As well, oxides of nitrogen (NO_x) are compounds that contribute to acidic deposition. Naturally occurring nitrogen in the air, combined with nitrogen released during the combustion of fossil fuels, is transformed into NO_x. Through a series of chemical reactions, nitrogen oxides are converted to nitric acid (HNO_3).

Alberta Guidelines Sulphur Dioxide
One Hour - 0.172 ppm average concentration
24 Hour - 0.057 ppm average concentration
Annual - 0.011 ppm arithmetic average

pH

The acidity of a substance is referred to as pH. The pH scale is numbered from 0 to 14, with a reading of 7 being classed as neutral. A pH value below 7 indicates an acidic condition while readings above 7 are a basic or alkaline. It must be remembered that the pH scale is logarithmic. This means that a change from one number to another is a factor of 10. A difference of one scale number (i.e. pH 7 to 8) means a difference of 10 times from the first to the second value.

pH Scale

pH Value	
	BASIC
14	
13	household lye
12	bleach
11	household ammonia
10	
9	baking soda
8	eggs, sea water
7	NEUTRAL
6	spring water
5	
4	orange juice
3	vinegar
2	lemon juice
1	battery acid
	ACIDIC

Acid Deposition in Alberta

SO_2 is emitted by many different industries. These include natural gas processing (sulphur recovery sour gas plants, flaring sour gas plants, sour oil batteries, and well testing flaring), oil sands, and electric power generation.

Emissions of SO_2 from the natural gas processing industry in Alberta peaked in 1972 at 460 kilotonnes per year, then decreased to about 300 kilotonnes per year in 1982 and have remained at that level ever since. Although natural gas production has increased in the province, SO_2 emissions from the industry have leveled off because the Alberta government introduced sulphur recovery requirements for sour gas plants.

Emissions from the oil sands sector in Alberta also gradually declined through the 1970's due to operational improvements. Between 1971 and 1995, SO_2 emissions from the oil sands plants were around 150 kilotonnes each year, even though their annual production of synthetic crude oil increased from about 2 million to 14 million cubic metres during the same period.

Emissions from the electric power generation sector in Alberta have showed a distinct upward trend from 1971 to 1995. This is directly related to the increased demand for power in the province.

1998 Levels of Sulphur Dioxide in Alberta

The 1-hour and 24-hour guidelines for SO_2 were not exceeded during 1998.

Table 9.0

Annual Average Sulphur Dioxide Concentrations (ppm)

Station Name	1993	1994	1995	1996	1997	1998
Calgary East	.0029	.0037	.0039	.0040	.0033	.0036
Edmonton East	.0032	.0028	.0024	.0028	.0029	.0024
Fort Saskatchewan	.0016	.0022	.0021	.0023	.0023	.0019

Table 10

1998 Quarterly and Annual Averages for Sulphur Dioxide (ppm)

Station	Jan - Mar 1998	Apr - Jun 1998	Jul - Sep 1998	Oct - Dec 1998	Annual Mean 1998
Edmonton East	0.003 (0.004)	0.002 (0.002)	0.002 (0.002)	0.003 (0.003)	.0024 (.0028)
Calgary East	0.005 (0.004)	0.003 (0.002)	0.004 (0.003)	0.004 (0.004)	.0036 (.0036)
Fort Saskatchewan	0.003 (0.003)	0.001 (0.001)	0.001 (0.001)	0.002 (0.001)	.0019 (.0021)

(Numbers in brackets represent the average for 1993-1998)

Table 11

Annual Average pH values of precipitation (1993-1998)

Station	1993	1994	1995	1996	1997	1998
Beaverlodge	5.0	5.0	4.9	5.0	5.2	5.0
Calgary	5.1	5.3	5.4	5.6	5.8	5.7
Cold Lake	5.4	5.2	5.3	5.5	5.3	5.6
Fort McMurray	4.7	4.8	4.8	4.9	5.3	4.9
Kananaskis	5.0	5.0	5.2	5.1	5.1	5.1
Suffield	5.1	5.2	5.5	5.3	5.4	5.6

In 1998, the lowest average pH of precipitation was recorded at Fort McMurray while the highest overall average pH was in Calgary (Table 11). These readings are consistent with the high SO_2 emissions in the Fort McMurray area and common occurrence of wind-blown dust in Calgary.

Since most of the soils in Alberta are naturally basic, dust from the soils tends to buffer the effects of any acidic deposition. Surveys conducted during the 1980s and early 1990s found that the northern half of Saskatchewan and northeastern corner of Alberta contain the most sensitive soils to acid deposition throughout the prairies. The Clean Air Strategic Alliance SO2 Management Project Team recommended Alberta adopt **critical loads** and **target loads** to manage acid deposition.

It is difficult to link emissions with acid deposition because of the complex relationship between meteorological conditions and sources. However,

Critical Load

Critical load is defined as the highest amount of acidic deposition that will not cause chemical changes leading to long-term harmful effects. The critical load value differs from that of the target load.

Target Load

The target load is the maximum level of acidic atmospheric deposition that affords long-term protection from adverse ecological consequences, and that is practically achievable.

mathematical modelling does provide a cost-effective way to link emissions with deposition given these complex relationships.

Recent acid deposition modelling results (Cheng *et al.* 1997) suggest that Alberta's soil and water currently receive less than 40% of their designated critical loads. These results, however, are applied to relatively large areas (1^o latitude by 1^o longitude). Local events, especially those close to emission sources, may produce higher levels of acid input relative to critical loads.

Alberta's Response to Acid Deposition

Alberta is the second highest emitter of acidifying emissions in Canada. However, the province is in the enviable position of being able to establish critical/target loads *before* adverse environmental effects are observed. In Europe and eastern Canada, governments have had to apply management methods in response to environmental damage that *already* exists.

Alberta Environment conducted a three-year Alberta Acid Deposition Program between 1991 and 1993. The purpose of this program was:

- To establish reliable methods to predict acid deposition within Alberta,
- To provide scientific and technical knowledge for limiting acid deposition to protect sensitive forest, lake, and soil systems in Alberta, and
- To develop monitoring techniques for wet and dry deposition of acid substances.

The program was a follow-up to the Alberta government/Industry Acid Deposition Research Program carried out between 1985 and 1987. Building on this prior research, the Clean Air Strategic Alliance (CASA) established an SO_2 Management Project Team to recommend a comprehensive system to manage SO_2 emissions in Alberta. In 1997, the team recommended a system to link the day-to-day management of SO_2 emissions in Alberta. The system would allow for periodic evaluations and improvements. Through this system, SO_2 would be managed in an environmentally sound and economically efficient manner.

Following up on the recommendations of the SO_2 Management Project Team, the CASA SO_2 Management Implementation Coordination Team is developing plans for the following:

- A voluntary initiative for enhanced performance, and
- Managing the "gap" between actual environmental conditions and the environmental limits.

The emissions "gap" is the difference between existing emissions and emissions at critical levels. CASA is working to manage this gap while it seeks ways to improve air quality. These goals can be achieved by:

- Educating industry about planning and identifying options,
- Rewarding superior performance in reducing emissions,
- Establishing emission credits, economic instruments and incentives, as well as plans to manage emissions, and
- Employing existing ambient objectives and regulatory tools, including approvals from Alberta Environment.

The concept of "managing the gap" was adapted from the "keeping the clean areas clean" concept outlined in the Canada-Wide Acid Rain Strategy for Post-2000.

4.6 Air Toxics

Sources of Air Toxics

Air **toxics** are poisonous airborne substances that exist in the atmosphere either as gases, aerosols or particulate contaminants.

Improved knowledge about atmospheric pollution has recently generated government and public concern about emissions of air toxics or hazardous air pollutants. This group of compounds includes:

- Metals and metalloids, such as arsenic, cadmium, lead and mercury,
- Respirable mineral fibres, such as asbestos,
- Inorganic gases, such as fluorides, chlorine and sulphur,
- Non-halogenated organic compounds, such as benzene, aldehydes, 1,3-butadiene, polycyclic aromatic hydrocarbon (PAHs), and
- Halogenated organic compounds such as dioxins, chloroform, vinyl chloride and polychlorinated biphenyl (PCBs).

In Canada, a substance is defined as an air toxic substance if it enters the atmosphere in a quantity or concentration and under the following conditions:

- The substance has or may have an immediate or long-term effect on the environment,
- The substance constitutes or may constitute a danger to the environment on which human life depends, or

What does Toxic Mean?

Toxic comes from the Greek word *toxikon*, which referred to the poison smeared on the tip of an arrow.

- The substance constitutes or may constitute a danger to human life or health.

Human exposure to these substances at sufficient concentrations and duration can result in cancer, poisoning, and rapid onset of sickness, such as nausea or difficulty in breathing. Other less measurable effects include immunological, neurological, reproductive, developmental, and respiratory problems. Substances deposited onto soil or into lakes and streams affect ecological systems and can affect human health through food contamination.

Air Toxics in Alberta

Potential sources of air toxics in Alberta include:

- Building materials,
- Chemicals,
- Food processing and animal by-products,
- Metals and minerals processing,
- Oil and gas production,
- Power plants,
- Solvents from dry cleaning and printing facilities,
- Vehicle exhausts, wood burning stoves and fire places,
- Waste incinerators (including flaring), and
- Wood fibre products.

Information about emissions of air toxics in Alberta is available in the National Pollutant Release Inventory (NPRI) database on-line at http://www.ec.gc.ca/pdb/npri/npri_home_e.cfm.

Gas Flaring

In Alberta, solution gas **flaring** has been identified as a human and animal health concern. In 1995, Alberta produced 162 trillion cubic metres of natural gas. Of this amount, 1.5 % was considered waste gas and was flared to the atmosphere. Gas is flared when economic and physical factors limit the opportunity to collect, process and market the gas. Examples of this would be when there is no access to pipelines or the gas volume may be too low. In these cases, excess gas is burned off. All **sour gas** is flared to eliminate a possible hazard to workers and nearby residents.

Sources of waste gas include:

- Gas liberated during the production of oil (solution gas),
- Heavy oil and conventional oil production installations,

Flaring

Flaring is the controlled burning of gases or vapours from an oil or natural gas installation.

- Production testing of gas and oil wells, and
- Gas from depressurising pipelines and processing equipment during maintenance and emergencies in the production and processing of natural gas.

Solution gas from oil installations is the main source of flare emissions, accounting for 73 % of total volumes flared in 1995. However, most solution gas produced in Alberta is not flared. About 92 % of the solution gas produced in Alberta is gathered, processed and sold.

Solution Gas & Sour Gas

"Solution Gas is natural gas found in solution with oil or bitumen. Sour Gas is natural gas that contains hydrogen sulphide H_2S. Unless a concentration is specified ... sour gas is defined as gas that contains H_2S in sufficient quantities to pose a public safety hazard if released or to result in unacceptable off-lease odours if vented to the atmosphere." *Alberta Energy and Utilities Board - Guide 60: Upstream Petroleum Industry Flaring Requirements*

Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) are chemicals formed during the incomplete burning of substances such as gasoline, diesel, oil, coal, wood and garbage. Tobacco smoke and charbroiled meats are also common sources of PAHs. There are more than 100 different PAHs with varying levels of toxicity. PAHs usually occur as complex mixtures (for example, as part of combustion products such as soot and smoke) and not as single compounds. PAHs occur in the atmosphere as vapours or attached to dust particles. The primary sources of PAHs in urban Alberta are exhaust emissions from vehicles. Other outdoor sources include wood smoke from fireplaces and smoke from forest fires and industrial facilities.

Benzo(a)pyrene (pronounced benzo *alpha* pyrene), the most well-known PAH, is monitored in Edmonton, Calgary, and Fort Saskatchewan. Observed annual average concentrations are much higher at stations located in the vicinity of heavily used traffic arteries. A seasonal trend in benzo(a)pyrene is evident at all monitoring stations. Much higher concentrations are evident in the fall and winter than in the spring and summer seasons. The reason for such results is that meteorological conditions tend to inhibit dispersion of substances.

Alberta's Response to Air Toxics

The Alberta government and most major Alberta industries are participating in the Accelerated Reduction/Elimination of Toxics (ARET) Program. ARET has expanded from a private-sector initiative to a national program. It is an experiment to determine whether voluntary commitments to reduce or eliminate emissions can achieve environmental goals faster and with more flexibility than regulations alone. It is also an example of how governments, citizens' groups and industry can work together to develop joint approaches to important environmental issues.

Table 12

Annual Average Benzo (a) Pyrene Concentrations at Alberta Stations (ng/m^3)

Year	Edmonton			Calgary			Fort
	Central	Northwest	East	Central	Northwest	East	Saskatchewan
1982	0.2	0.1	0.1	0.4	0.1	0.2	0.0
1983	0.2	0.1	0.1	0.3	0.1	0.2	0.0
1984	0.3	0.1	0.1	0.3	0.1	0.2	0.1
1985	0.2	0.1	0.1	0.1	0.0	0.1	0.0
1986	0.4	0.2	0.1	0.2	0.1	0.2	0.1
1987	0.2	0.1	0.1	0.3	0.1	0.1	0.1
1988	0.5	0.2	0.1	0.5	0.1	0.3	0.1
1989	0.3	0.3	0.1	0.4	0.1	0.2	0.0
1990	0.3	0.3	0.1	0.2	0.0	0.1	0.0
1991	0.1	0.1	0.0	0.1	0.0	0.1	0.0
1992	0.2	0.1	0.0	0.1	0.0	0.1	0.0
1993	0.2	0.2	0.1	0.2	0.1	0.2	0.1
1994	0.4	0.4	0.2	0.4	0.2	0.2	0.2
1995	0.2	0.2	0.1	0.2	0.1	0.2	0.1
1996	0.2	0.2	0.1	0.2	0.1	0.2	0.1
1997	0.1	0.2	0.1	0.1	0.0	0.2	0.1
1998	0.2	0.2	0.1	0.2	0.1	0.2	0.1
1999	0.1	0.1	0.1	0.1	0.0	0.1	0.1

In Alberta, a management program for industrial air toxics is administrated by Alberta Environment. The major components of the management system include:

- ambient guidelines or prescribed ambient levels,
- source emission standards,
- plume dispersion modelling,
- ambient air monitoring,
- source emissions monitoring,
- environmental reporting,

- emission inventory,
- approvals,
- inspection/abatement, and
- enforcement.

The management program is similar to that for pollutants such as sulphur dioxide and oxides of nitrogen.

The Clean Air Strategic Alliance (CASA) established two multi-stakeholder project teams to review and develop ways to manage air toxics in Alberta.

The objectives of the CASA Air Toxics Project Team were to:

- Identify and substantiate any Alberta-specific issues,
- Develop a process for assessing these issues,
- Make recommendations on how continuous improvement can be built into this process, and
- Recommend management options, including reporting and updating.

As a result, the CASA Flaring Project Team developed recommendations that address potential and observed impacts associated with solution gas flaring. The team recommended that Alberta work to eliminate routine solution gas flaring with the following hierarchy to guide decisions:

- Eliminate routine solution gas flaring,
- Reduce volume of solution gas flared, and
- Improve the efficiency of solution gas flared.

Industry and regulators have accepted a new flaring management framework. The framework calls for a reduction of up to 70% of the volume of solution gas currently being flared. As well, new standards will be applied to both new and existing flares to improve their combustion efficiency and reduce products of combustion released to the atmosphere.

4.7 Particulates

Sources of Particulates

Particulates include a wide variety of tiny particles, invisible to the naked eye. They include both solid matter and liquid aerosols that are small enough to remain in the air for long periods of time. Particulates come from large and small sources. These include soil, roads, agricultural dust, vehicles, and industrial emissions, as well as smoke from forest fires, agricultural burning, household fireplaces, barbeques and cigarettes. Particulates are a key component in many atmospheric processes, including the production of photochemical smog, acid deposition, reduced visibility, and possible changes to our climate.

The term "total suspended particulates" (TSP) is a measure of particles in the air that are captured on a filter and then weighed. These particles range in size up to 50 **micrometres** in diameter.

Recently, researchers have paid increased attention to the human health implications of airborne particles, especially the size of the particles. Research has shown that small particles are a more serious health concern than previously believed. To enable researchers to more accurately measure such particles in the air, researchers measure particulate matter (PM) rather than total suspended particulates.

Standards or guidelines for PM are based on two ranges of particle size: PM_{10} or $PM_{2.5}$. This means the sampling equipment captures either any particles smaller than 10 microns in diameter (PM_{10}), or just particles smaller than 2.5 microns in diameter ($PM_{2.5}$). Note that PM_{10} measurements include the smaller $PM_{2.5}$ particles. To determine the amount of particulate matter in an air sample, the particles are collected on a filter. Particles larger than PM_{10} are excluded and then the remaining particles are weighed. Therefore, PM_{10} is only one part of what was previously measured in total suspended particulates.

All measures of particulates - TSP, PM_{10} and $PM_{2.5}$ - are measured as mass per volume of air, usually micrograms per cubic metre ($\mu g/m^3$). The amount of particulates found under natural conditions in the air is very small, usually about 6 $\mu g/m^3$ in western Canada.

$PM_{2.5}$ particles differ from the larger PM_{10} particles in more than just size. They have different sources and chemical composition and they behave differently in the air. Particles larger than 2.5 microns settle to the ground more quickly and remain in the air for only a few hours to a few days. Particles smaller than 2.5 microns may persist in the air for a few days to a few weeks.

How small is a micrometre?

One micrometre is one one-thousandth of a millimetre. The symbol for a micrometre is μm. To give an idea of how small that is, a human hair is about 500 micrometres in diameter. A micrometre is sometimes called a micron.

Larger particles in the air often come from activities such as grinding and other mechanical processes. When PM_{10} particles are released from sources directly into the air, these are called primary particulates. Secondary particulates, which are finer particles, less than 2.5 microns in size, may be formed when physical and chemical reactions occur between gases emitted into the air. Particles larger than 2.5 microns are often made up of materials that are typical of the earth's crust. These include iron, calcium, silicon and aluminium. Sodium and calcium particles may also come from sea spray carried by the wind.

Different processes create $PM_{2.5}$ particles. These processes include the condensation of vapours or gases, the combustion of various materials, coagulation of smaller particles or interactions of gases. Gases that create $PM_{2.5}$ particles include SO_2 (sulphur dioxide), NO_x (oxides of nitrogen), and VOCs (volatile organic compounds), as well as various other gases that often come from industries, vehicles and fires. $PM_{2.5}$ particles consist primarily of ammonium, sulphate and nitrate, elemental carbon, and hundreds of other organic compounds.

In high concentrations, suspended particulates can harm respiratory function in humans. The degree to which these particles are harmful depends, in part, on their chemical composition. However, not much is known about the effects of particles of different chemical composition. What is known is that particles small enough to be inhaled, sometimes called inhalable particulates, can affect human health. The effects may include reduced pulmonary function and aggravation of existing pulmonary and cardiovascular disease.

Smaller particles, such as $PM_{2.5}$, seem to have more effect on human health than larger particles. This is why they are measured separately from PM_{10}. The larger particles tend to be deposited in the upper respiratory tract, in the nose and throat, while smaller particles travel deeper into the lungs. As a result, they can cause breathing difficulties and possibly permanent damage to our lungs. Approximately 25 to 60% of inhaled particles smaller than 2.5 microns can be deposited deep in the lungs, as compared to less than 5% of PM_{10}.

The toxicity of the particles varies, depending on their chemical composition. A number of potentially harmful substances have been found in $PM_{2.5}$ particles. Sulphates produced from sulphur dioxide emissions are acidic and may react directly with our lungs. Several studies have shown that trace metals such as lead, cadmium and nickel are more concentrated in $PM_{2.5}$ than in larger particles.

Particulates in Alberta

Alberta's *Environmental Protection and Enhancement Act* authorizes development of guidelines for air pollutants. These guidelines include recommended levels for particulates and dust.

Alberta Guidelines Particulates (Total Suspended Particulates)
100 micrograms per cubic metre as a 24-h average concentration

Alberta Environment, in cooperation with Environment Canada, has monitored ambient concentrations of particulates in downtown Edmonton and Calgary since 1984. At some sites, there were peaks in particulates in the morning and late afternoon. This suggests particulate levels are related to traffic flow. Silicon was the most abundant element found in the PM_{10} levels, while sulphate made the largest contribution (80%) to $PM_{2.5}$ readings (Cheng *et al.* 1997). As table below shows, PM_{10} and $PM_{2.5}$ levels, as well as amounts of nitrates, lead and bromine, decreased over the study period. No significant trends were observed for silicon, sulphur, chlorine, magnesium, formate or acetate. Increasing trends were observed in $PM_{2.5}$ calcium and potassium at the Edmonton site.

Sulphate, silicon, calcium, iron and sulphur particulate concentrations generally peaked in the spring, while nitrate and chlorine particulate concentrations reached definite peaks in the winter. Peaks in the spring likely are due to increased circulation of sand and salts from road surfaces. High nitrate concentrations in the winter correspond with higher concentration of oxides of nitrogen in the air. These concentrations come from combustion of fossil fuels, including vehicle exhaust.

Alberta's Response to Particulates

Alberta is participating with the federal government in a PM_{10} and $PM_{2.5}$ monitoring program. This program has been in operation since 1984 under the National Air Pollution Surveillance (NAPS) network. The NAPS network focuses primarily on urban areas with some rural monitoring sites.

Alberta also participates with the federal government and representatives of other provinces and territories to develop Canada-Wide Standards for various contaminants, including particulate matter in air. Four key elements form the basis of the Canada-Wide Standards:

- A numeric level,
- A timeline for implementation,
- An initial set of jurisdictional actions, and
- A protocol for monitoring and reporting progress.

Table 13

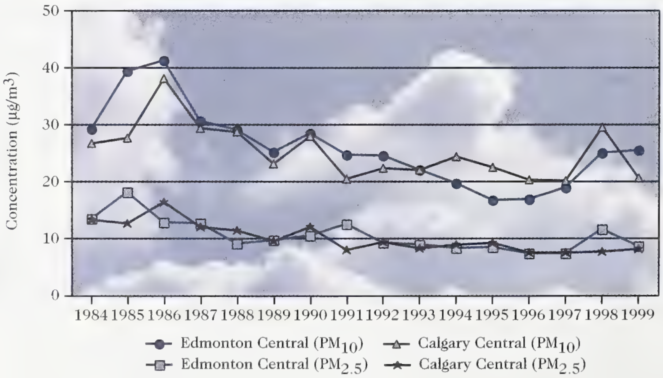
Annual Average Particulate Matter Concentrations (μg/m³)*

Year	$PM_{2.5}$ Edmonton Central	$PM_{2.5}$ Calgary Central	PM_{10} Edmonton Central	PM_{10} Calgary Central
1984	13.47	13.32	29.33	26.74
1985	18.26	12.76	39.47	27.78
1986	12.89	16.56	41.40	38.27
1987	12.68	12.15	30.78	29.49
1988	9.19	11.44	29.16	28.83
1989	9.76	9.65	25.31	23.17
1990	10.55	12.18	28.58	28.00
1991	12.55	7.98	24.70	20.62
1992	9.34	9.38	24.62	22.41
1993	8.97	8.35	22.06	22.14
1994	8.29	9.05	19.82	24.46
1995	8.58	9.29	16.83	22.54
1996	7.38	7.64	16.90	20.39
1997	7.37	7.64	19.04	20.31
1998	11.60	7.68	25.09	29.65
1999	8.60	8.27	25.61	20.66

* Based on 24-hour samples collected once every sixth day in accordance with the National Air Pollution Surveillance program.

Figure 13

Long-Term Trend in Particulate Matter Concentrations



5.0 Global Air Issues

Many of the air quality issues discussed in earlier chapters have local or regional effects. There are also air quality issues that affect the atmosphere as a whole and the effects are seen around the world. Two major global air issues are stratospheric ozone depletion and climate change. Both issues are have attracted a lot of attention from not only the scientific community, but also the worldwide media and the general public.

These issues may seem overwhelming when viewed in the global context. However, it is important to remember that our seemingly small personal actions can impact both of these important air issues.

5.1 Stratospheric Ozone Depletion

The ozone layer refers to a natural concentration of ozone in the stratosphere. This ozone plays a critical role in filtering the amount of **ultraviolet (UV) radiation** that reaches the earth's surface from outer space. UV radiation, in high enough doses, is harmful to plants, animals and humans.

Ozone in the stratosphere is constantly being created and destroyed. The natural production and destruction of ozone is a complex process. UV radiation, especially UV-B and UV-C radiation, and other compounds in the stratosphere are all part of this process. The temperature of the stratosphere also has a bearing on the process. Colder temperatures can accelerate ozone destruction.

Concerns about the ozone layer first arose when a reduction in the amount of ozone over Antarctica was observed in the mid 1980s. The depletion of the ozone layer over Antarctica was widely reported as an "ozone hole." The depletion was due to the presence of certain human-produced compounds in the stratosphere. These compounds react with ozone in the stratosphere and cause a net destruction of ozone. Chlorofluorocarbons (CFCs) were identified as the main compounds found to destroy the ozone in the stratosphere.

CFCs are human-produced chemicals created in the 1930s as a replacement for ammonia in refrigerators. They also were used as a propellant in aerosol containers. Normal meteorological mixing processes in the lower atmosphere can transport these compounds into the stratosphere. Because CFCs are very stable compounds, they do not break down (chemically) very quickly. Some types of CFCs can exist for up to 200 years before breaking down.

Ultraviolet (UV) radiation

Ultraviolet (UV) radiation refers to radiation at the wavelengths from 200 to 400 nanometres (nm). This part of the spectrum is further broken down into 3 subregions:

UV-A from 320-400 nm

UV-B from 280-320 nm

UV-C from 200-280 nm

Of these, UV-C is the most energetic of three different forms of UV radiation and the most dangerous to life on earth. However, almost all UV-C radiation is absorbed in the stratosphere by ozone and oxygen.

While CFCs are considered the main threat, they are not the only ozone-depleting substances in our environment (see Table 14).

Table 14

Major Ozone-Depleting Substances

Ozone-Depleting Substance	Major use
Chlorofluorocarbons (CFCs)	• as refrigerants in refrigeration and air-conditioning systems • as propellants • as solvents, reagents, manufacture of foams and medical uses
Halons	• as fire suppressants
Methyl Chloroform (MCF)	• as solvent
Carbon Tetrachloride (CCl_4)	• as solvent and reagent
Hydrochlorofluorocarbons (HCFCs)	• as an interim replacement for CFCs
Methyl Bromide	• in pesticides

(Source: Environment Canada, 1993b)

Ozone Depletion in Alberta and Around the World

Across Canada, observations of UV-B radiation at ground level have shown a 10% increase between 1986 and 1996 (Environment Canada 1997a), reflecting a decline in ozone levels. However, in 1998, ozone levels over the Arctic did not decline as much as in previous years. The temperature in the stratosphere was not as cold as in the previous two years and this appears to have reduced the depletion. Ozone levels do recover somewhat in the spring and summer when the temperature in the stratosphere warms.

A recent study of Alberta UV-B trends (Shen 2000) uses data from the Stony Plain measuring station from 1992 to 1996. The study indicates that the integrated irradiation over the UV-B range decreased approximately 21% during the summer months of May through August. The UV-B readings for November to February increased approximately 11% at the same station.

These and other studies indicate that the rate of ozone destruction may be slowing down following the banning of major ozone-depleting substances. However, many experts feel it will take until at least 2050 for ozone levels to return to pre-1980 levels.

The main concern about the thinning of the ozone layer is that increased UV radiation, particularly the UV-B radiation, will lead to adverse health effects for humans and ecological systems. Increased exposure to UV-B radiation has been linked to sunburn, skin cancer, a weakened immune system, and increased eye cataracts in humans. It may also affect food chains in the ecosystem and reduce crop yields.

The Global and Alberta Response to Ozone Depletion

To prevent further thinning of the ozone layer, the world's nations agreed in 1987 to reduce and limit the emission of ozone-depleting substances. This agreement is known as the Montreal Protocol. The protocol aimed to cut production of CFCs to 50% of the 1986 levels by the year 2000. Canada was one of the main initiators of the Montreal Protocol.

There have been several amendments to the Protocol, which Canada has supported. At an international meeting in London in 1990, the nations of the world decided to phase out CFCs completely by 2000. As well, additional substances were included in the list of ozone-depleting substances to be banned. In 1994, a meeting at Copenhagen hastened the process to phase out CFC production by moving up the deadline to 1996. Canada was one of the countries to reach this target on schedule. An immediate effect of these agreements was that alternatives now have to be found to replace the phased-out substances.

In March 1998, Canada became the first country to ratify the latest set of changes to the Montreal Protocol. These changes involve a ban on importing and exporting methyl bromide, another ozone-depleting substance, and creating a worldwide license system to keep track of ozone-depleting substances.

The federal and provincial governments have adopted the National Action Plan for Recovery, Recycling and Reclamation of Chlorofluorocarbons (CFCs) to help deal with CFCs. This National Action Plan is being expanded and updated. In addition, Alberta is an active participant in the Federal-Provincial Working Group on Ozone-Depleting Substances.

Alberta's *Environmental Protection and Enhancement Act* (EPEA) regulates the release of substances into the environment. In 1992, the production of ozone-depleting substances was banned in Alberta under the EPEA. On September 1, 1993, the Alberta Ozone-Depleting Substance Regulation was enacted. This regulation prohibits the release and use of ozone-depleting substances and products containing these substances.

The regulation has some provisions related to servicing equipment that contains ozone-depleting substances. Some other exemptions in the regulation allow for

essential use in fire-fighting equipment and health care applications. Regulatory offences and penalties are also specified in the regulation. The maximum fine for violation is $50,000 for individuals and $500,000 for corporations. Alberta's active enforcement program produced a major prosecution regarding ozone-depleting substances in 1997, which resulted in a total penalty of $300,000.

Future directions

Canada has already met its obligations under the Montreal Protocol for phasing out the production of ozone-depleting substances. It is expected the use of ozone-depleting substances such as CFCs, halon, methyl chloroform and carbon tetrachloride will also be phased out within the next 10 years. In the next 20 years, hydrochlorofluorocarbons (HCFCs) will also be phased out. HCFCs are used as interim alternatives for CFCs since they have a much lower ozone depleting potential. This means alternatives with no adverse environmental effects need to be developed and made available for use.

In the future, there will be further prohibition on the use of CFCs for recharging air conditioning systems on older vehicles. Repairing these older units will require non-ozone-depleting refrigerants. A Halon Management Plan must also be developed to phase out the use of halons in fire protection systems. Treatment or disposal alternatives for ozone-depleting substances, especially halons, are required. In addition, ongoing public education will help to ensure we continue to protect the ozone layer.

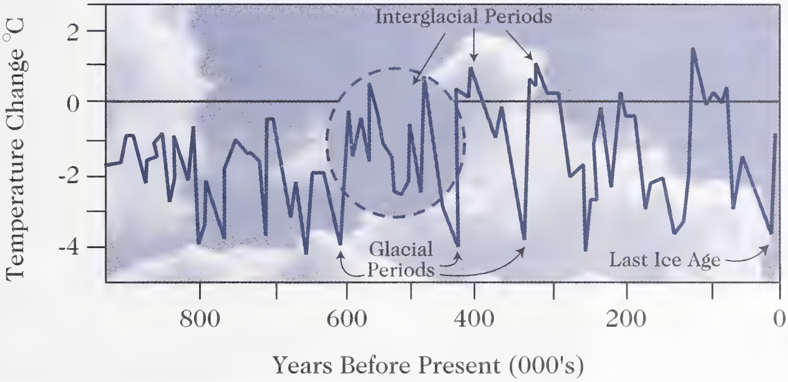
5.2 Climate Change

A large body of research is being directed to determine the causes, extent and magnitude of climate change. The United Nations Intergovernmental Panel on Climate Change (IPCC) says that "the balance of evidence suggests that there is a discernible human influence on global climate" (Houghton *et al.* 1996). This implies that both evidence and counter-evidence exist for the human influence on climate and the timing, nature and magnitude of the impacts.

The Earth's climate system is extremely complex and dynamic. Many factors affect our climate, including composition of the atmosphere, solar radiation, the earth's orbit and volcanic eruptions. Our climate has varied in the past - the ice ages are strong evidence that our climate has not always been as it is today.

Figure 14

Temperature Variations over the last one million years



(Environment Canada 1993a)

The Greenhouse Effect

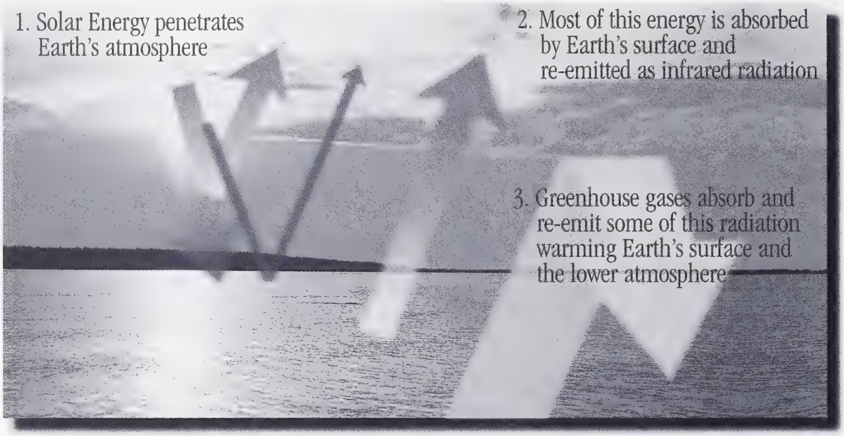
The greenhouse effect refers to the natural role of the atmosphere in the global balance of heat energy. Short wave radiation from the sun passes through the atmosphere and heats the Earth's surface. This energy is then radiated from the Earth like a giant radiator. Some of the gases in the atmosphere absorb this heat energy. This warms the atmosphere. Without the natural greenhouse effect, the average temperature of the Earth would be much lower and life as we know it would not exist. Without our atmosphere, most of the heat received by the Earth would escape to outer space and the Earth's average temperature would be a cold -18°C. The warming effect of the natural greenhouse raises the average global temperature by approximately 33 degrees, to around 15°C.

The main greenhouse gases found in the atmosphere are:

- Water vapour (H_2O)
- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Ozone (O_3)
- Halocarbons, such as chlorofluorocarbons (CFCs)

Figure 15

The Greenhouse Effect



Except for the halocarbons, all the main greenhouse gases are found naturally in the atmosphere. Water vapour is the most important greenhouse gas, in terms of its effect on heating the atmosphere. The amount of water vapour in the atmosphere, however, is not significantly affected by human activities. Human activities do add the other greenhouse gases to the atmosphere, the most significant being carbon dioxide, mainly from burning fossil fuels such as coal, oil and natural gas. Some agricultural practices add methane, while industrial processes add other greenhouse gases. The addition of human-produced greenhouse gases to the atmosphere is called the "enhanced greenhouse effect."

The main sources of human-produced greenhouse gas emissions are associated with producing and using energy. In Canada, energy production and related processes account for 85% of greenhouse gas emissions (Environment Canada 1997a). Table 15 shows 1997 greenhouse gas emissions by sources for Canada and Alberta.

As human activities add greenhouse gases to the atmosphere, more long-wave radiation is absorbed by these gases. This may lead to additional warming of the Earth's temperature. However this warming is not a certainty. There are other mechanisms within our climate system that may work against it. For example, a warmer atmosphere can hold more moisture, leading to greater cloudiness and more reflection of the short-wave radiation back from the sun. This could have a cooling effect. Is this cooling enough to offset the possible rise in global

Table 15

Greenhouse Gas Emission Estimates for 1997 in Canada and Alberta

Source	Canadian Emissions		Alberta Emissions	
	Kilotonnes - CO_2 Equivalent	Percentage	Kilotonnes - CO_2 Equivalent	Percentage
Energy (includes transportation, stationary sources and fugitive emissions)	537,000	78.8	167,000	83.2
Industrial Processes	56,000	8.2	12,000	6.0
Solvent Use	900	>.01	43	>.01
Agriculture	63,000	9.3	20,000	10.0
Land Use Change & Forestry	1,700	>.01	570	>.01
Waste	23,000	3.5	1,000	5.0
TOTAL	681,600		200,613	

(Neitzert, F. *et al.*, 1999)

temperature from the addition of human-produced greenhouse gases? There are many uncertainties around this issue.

Researchers use computer models to assess and predict the enhanced greenhouse effect. These global climate models run on very powerful computers. No matter how sophisticated the model is, the climate system is even more complex. There are uncertainties regarding important processes like the role of clouds and oceans. In addition, the models can only estimate the climate for large areas. At present, models provide little detail at regional and local levels. Global climate models cannot directly predict extreme weather events such as storms and drought, although there are indications from some models that extreme events may increase in frequency. Extreme weather events have been linked to El Niño, but the relationship between El Niño and enhanced global warming is not clear.

Greenhouse Gases in Alberta

Canada contributes approximately 2% of the world's greenhouse gas emissions, ranking second on a per-capita basis to the United States (Environment Canada 1997a). This figure reflects the fact that Canada is a vast northern country with a cold climate, long distances between population centres, and a resource-based economy.

1997 statistics (Nietzert *et al.* 1999) show that Alberta accounts for approximately 30% of Canadian greenhouse gas emissions and the highest per-capita release of greenhouse gases in Canada. This is mainly a result of our energy-based economy. Alberta is the largest producer of oil and gas in Canada, and greenhouse gases are released during oil and gas production.

Alberta is a net exporter of energy resources. Most of Alberta's greenhouse gas emissions are from fossil fuel production and power generation. Alberta's emissions of greenhouse gases are increasing, primarily to meet energy demands from the rest of Canada and the United States. Increased exports accounted for more than 80% of the emissions growth in the petroleum industry and about 31% of Canada's total increase in emissions from 1990-1995 (Government of Alberta 1997).

Energy resources exported from Alberta displace other energy sources that produce greater quantities of greenhouse gases. While Alberta's emissions continue to rise, the net result is that some other regions are able to reduce their emissions by using more efficient and less carbon-intensive fuels imported from Alberta.

Alberta Climate Trends

Alberta's record of weather observations has been kept for little more than 100 years. However, we can make inferences about Alberta's past climate by looking at other indicators, such as sediments from lake bottoms, tree rings and pollen studies (Environment Canada 1997b).

We can also identify trends in the existing data. By comparing data for two recent periods (1975-1985 and 1985-1995) with the long-term averages (1905 to 1995), we can see how temperature and precipitation have changed over the past century in Alberta.

This comparison shows that the average temperature for 1985-1995 was higher than the long-term average. There were also higher average maximum and minimum temperatures during the 1985-1995 period.

For the 1975-1985 period, the mean temperatures at the stations were closer to the long-term mean. Some stations were slightly warmer, others were slightly cooler and some (like Calgary and Lethbridge) were close to the long-term average. However, the maximum temperatures during this period were mostly lower than the long-term average maximum temperature by fractions of a degree, whereas the minimum temperatures were mostly higher than the long-term average minimum.

A recent study on the climate of Alberta (Shen 1999), using data from 1884 to 1996, indicates no upward trend in the maximum temperature. The study looked at 38 stations throughout the province. However, results showed an upward trend

of approximately 0.8 celsius degrees since 1920 in the minimum temperature. Total precipitation appears to increase slightly since the 1920s. However, the precipitation data is much more variable and more testing is needed to confirm the results.

Is it possible to draw conclusions about climate change from these studies? There is no doubt that the decade of the 1990s was one of the warmest in the last 90 years of record. Still, there have been warmer years on record and it is not clear whether this period confirms enhanced warming.

Implications

Alberta's records indicate some warming over most of the province and generally less snow and more rain in recent years. However, the factors causing these changes are not identified. The Intergovernmental Panel on Climate Change report suggests that human activities could possibly be influencing the global climate by releasing excess greenhouse gases into the atmosphere and world leaders have decided to take precautionary action. International meetings on climate change began with the Rio Summit in 1992 when more than 150 nations signed on to the Framework Convention on Climate Change aiming at a global reduction in greenhouse gas emissions. Subsequent developments led to the Kyoto Conference of December 1997, in which developed nations negotiated targets to reduce missions of greenhouse gases.

The Kyoto Protocol requires Canada to reduce its greenhouse gas emissions to 6% below its 1990 level by the year 2010. Since economic growth is closely associated with increase in greenhouse gas emissions, this is a very significant reduction, in light of the projected growth in the Canadian economy. There are also significant implications to Alberta as a major producer of oil and gas.

The climate change issue has both environmental and economic implications. Adapting to climate change and reducing greenhouse gas emissions both involve costs for the benefits obtained. Also, the uncertainties in various aspects of the issue mean risks have to be assessed before actions are taken.

The Alberta Response to the Issue

The principles for Alberta's response to climate change are based on precautionary action, equitable sharing of responsibilities, and flexible, cost-effective approaches to overall environmental improvement. The Alberta government says that actions should contribute to sustainable development and maintain the economic competitiveness of Canada. These principles are similar to those contained in Canada's National Action Program on Climate Change in which the Alberta government is an active participant and supporter.

Central to this program is the **Voluntary Challenge and Registry (VCR) program**, begun in 1994 as a voluntary initiative that allows for a "quick start" to reducing greenhouse gas emissions. Alberta organizations have led Canada in participating and supporting the VCR. As of October 1997, there were 98 Alberta-based organizations that have submitted either action plans or progress reports. In addition, Alberta organizations also contribute significant funding to the VCR program.

The Alberta government submitted a VCR action plan in October 1995 and aimed to reduce emissions in its own operations by 14.1 % from 1990 levels by 2000. In 1996, the Alberta government was the only province in the government category to receive an award for its achievements in the VCR program to reduce greenhouse gas emissions. In addition, the Alberta government's 1996 Progress Report was ranked fourth overall in an independent assessment of Canada's VCR action plans.

In 1997, the Alberta government established a Cabinet committee on climate change to consult with stakeholders in the province and to report to Cabinet on stakeholders' response.

In its 1998 report, the committee stated that "(we) agree with the assessment that the risk of greenhouse gas emissions contributing to climate change warrants precautionary measures - which would mean incurring prudent costs to achieve best efforts in reducing the growth in emissions."

In response to the report of the Cabinet Committee on Climate Change, the Alberta government held a roundtable on climate change. Albertans from all walks participated in the roundtable to "chart our course" and determine Alberta's response to the issue of climate change.

The roundtable endorsed forming Climate Change Central, a government/private sector partnership that is working with Albertans to address climate change and energy efficiency.

More information on Alberta's response can be found at the government's climate change website, http://www3.gov.ab.ca/env/climate/index.html.

The Voluntary Challenge and Registry

The Voluntary Challenge and Registry (VCR) Program is a key element of Canada's National Action Program on Climate Change. It invites Canadian companies and organizations to limit net greenhouse gas emissions, on a voluntary basis, by developing and implementing individual action plans. The role of the VCR is to recruit participants and to record and report on their action, commitments and achievements. The Registry component of the VCR is a permanent, open and public record of the commitments made and the actions taken by industry, business and government to limit emissions of greenhouse gases from their operations. The Registry allows organizations to learn from others and share information about innovative greenhouse gas reduction initiatives.

Participation, commitment and achievement form an overall framework for measuring the progress of the VCR. Participation must be accomplished first through a letter of commitment from interested organizations. This commitment is then demonstrated by developing an action plan. Action plans undertaken by different organizations show they are seriously addressing the need to reduce greenhouse gas emissions. Organizations are encouraged to refine their action plans on an annual basis. Achieving actual greenhouse gas reductions is the final step. Organizations are encouraged to measure the results of their actions. This may include improved energy efficiency, reduced emissions of greenhouse gases or increased emission offsets.

The VCR Program recognizes the performance of leading organizations in reducing greenhouse gas emissions. Governments record actual emission reductions achieved by participants. Participants are assured that those reductions will be credited against any future obligations required by government.

6.0 Summary

Trends

Over the past 20 years, air quality in Alberta has improved. The Index of the Quality of the Air for 1998 supports this conclusion. Improved technology and public awareness of air issues has helped this trend.

In 1998, Alberta's air quality was considered Good for over 95% of the year. Among all the reporting stations, there were only 11 hours where the air quality was considered Poor, and there were no incidences of Very Poor air quality.

The few incidents of Poor air quality are associated with stable weather patterns that prevent substances from being dispersed and removed from the air. Smoke from forest fires is often the cause of these incidents. Fortunately in Alberta, these types of conditions are short-lived.

The Future

Alberta Environment, along with industry, operates an extensive air-monitoring and reporting network. Industrial facilities in the province are regulated through government-issued approvals. Inspections and abatement strategies ensure high standards of air quality are maintained.

While we do enjoy good air quality in Alberta, there is always room for improvement. As well, other air quality issues are emerging that have to be considered. Issues such as climate change, air toxics and particulates are important, and will have to be dealt with.

Fortunately in Alberta there is a unique partnership — the Clean Air Strategic Alliance. This group of government, industry and environmental groups works together to deal with air quality problems. It is through this spirit of cooperation that progress can be made toward more improvements in our air quality.

In the future, technology will, as it has in the past, play a considerable role in improving air quality. There is also room for lifestyle changes and personal actions to help keep our air clean. All sectors of our province — government, industry, schools, environmental groups and the public at large — will have to play a significant role to ensure our air quality improves over the coming years.

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http://www.casahome.org

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http://www.casadata.org

Environment Canada - Clean Air
http://www.ec.gc.ca/air/introduction_e.cfm

National Pollutant Release Inventory
http://www.ec.gc.ca/pdb/npri/npri_home_e.cfm

*Due to the nature of the Internet, the addresses for these sites may change without notice.